Development Document for Effluent Limitations Guidelines

BUILDING, CONSTRUCTION, AND PAPER

Segment of the Asbestos Manufacturing

Point Source Category

FEBRUARY 1974

U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

DEVELOPMENT DOCUMENT

for

EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

for the

BUILDING, CONSTRUCTION AND PAPER SEGMENT OF THE ASBESTOS MANUFACTURING POINT SOURCE CATEGORY

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ABSTRACT

This document presents the findings of an extensive study of a segment of the asbestos manufacturing industry by the Environmental Protection Agency for the purpose of developing effluent limitations guidelines and Federal standards of performance for the industry to implement Sections 304, 306 and 307 of the "Act."

Effluent limitations guidelines contained herein set forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best available technology economically achievable which must be achieved by existing point sources by July 1, 1977 and July 1, 1983 respectively. The standards of performance for new sources contained herein set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives.

The development of data and recommendations in the document relate to a portion of the asbestos manufacturing category which contains the major water users in this industry. This segment was subdivided by process into seven subcategories Separate *effluent limitations were developed for each subcategory on the* basis of the level of raw waste loads as well as the degree of treatment achievable by suggested model systems. These systems include coagulation, sedimentation, skimming, neutralization, and certain in-plant modifications.

Supportive data and rationale for developments of the proposed effluent limitations guidelines and standards of performance are contained in this report.

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SECTION I

CONCLUSIONS

That part of the asbestos manufacturing industry covered in this document is classified into seven subcategories. The major factors in subcategorizing the asbestos products industry on the basis of product lines were raw waste loads and volumes of waste waters. Other factors further supported this decision, such as differences in in-plant processes, end-of-pipe control technologies, and the speed with which zero discharge could be realized for each subcategory.

The subcategories are as follows:

1. Asbestos-cement pipe,
2. Asbestos-cement sheet,
3. Asbestos paper (starch binder),
4. Asbestos paper (elastomeric binder),
5. Asbestos millboard,
6. Asbestos roofing products, and
7. Asbestos floor tile.

Recommended effluent limitations and waste control technologies to be achieved by July 1, 1977, and July 1, 1983, are summarized in Section II. It is estimated that the investment cost of achieving the 1977 limitations and standards by all plants in the industry is less than $3 million, excluding costs of additional land acquisition. The cost of achieving the 1983 level is estimated to be about $6 million for the industry, i.e., an additional $3 million over the 1977 level.

SECTION II

RECOMMENDATIONS

The recommended effluent limitations for the parameters of major significance are summarized below for the categories of asbestos products included in this document. Using the best practicable control technology currently available, the limits are as follows:

	Suspended Solids kg/kkg*	COD kg/kkg*
Asbestos-cement pipe	0.19	-
Asbestos-cement sheet	0.23	-
Asbestos paper (starch binder)	0.35	-
Asbestos paper (elastomeric binder)	0.35	-
Asbestos millboard	zero discharge	
Asbestos roofing	0.006	0.008
Asbestos floor tile	0.04**	0.09**

pH between the limits of 6.0 to 9.0 for all subcategories

*kg of pollutant/kkg of product

**Units: kilogram per 1,000 pieces (12"x12"x3/32")

Using the best available control technology economically achievable, no discharge of waste waters to navigable water is recommended as the effluent limitation guideline and standard of performance for all of the above categories of asbestos products. With the exception of asbestos-cement pipe and asbestos paper containing elastomeric binders, this limitation and standard of performance is recommended for all new point sources. These two excepted products should meet the limitations outlined as best practicable control technology currently available.

A more detailed explanation of these limitations including daily maximum limitations are contained in Section IX.

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) to the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish, within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operating methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the asbestos manufacturing source category.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b)(1)(A) of the Act, to propose regulations establishing Federal standards of performances for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F. R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the asbestos manufacturing source category, which was included within the list published January 16, 1973.

SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

The effluent limitations guidelines and standards of performance proposed herein were developed in the following manner. The point source category was first categorized for the purpose of determining whether separate limitations and standards are appropriate for different segments within a point source category. Such subcategorization was based upon raw material used, product produced, manufacturing process employed, and other factors. The raw waste characteristics for each subcategory were then identified. This included an analyses of (1) the source and volume of water used in the process employed and the sources of waste and waste waters in the plant; and (2) the constituents (including thermal) of all waste waters including toxic constituents and other constituents which result in taste, odor, and color in water or aquatic organisms. The constituents of waste waters which should be subject to effluent limitations guidelines and standards of performance were identified.

The full range of control and treatment technologies existing within each subcategory was identified. This included an identification of each distinct control and treatment technology, including both in-plant and end-of-process technologies, which are existent or capable of being designed for each subcategory. It also included an identification in terms of the amount of constituents (including thermal) and the chemical, physical, and biological characteristics of pollutants, of the effluent level resulting from the application of each of the treatment and control technologies. The problems, limitations and reliability of each treatment and control technology and the required implementation time were also identified. In addition, the non-water quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise and radiation were also identified. The energy requirements of each of the control and treatment technologies was identified as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology constituted the "best practicable control technology currently available," "best available technology economically achievable" and the "best available demonstrated control technology, processes, operating methods, or other alternatives." In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques process changes, non-water quality environmental impact (including energy requirements) and other factors.

Sources of Data

Unlike some industries, the waste waters from the asbestos manufacturing industry have received almost no attention in the engineering and pollution control literature. Very few plants have any information more extensive than the results of analyses of one or a few grab samples of the final effluent. The data used in this document were necessarily very limited and were derived from a number of sources. Some of the sources included published literature on manufacturing processes, EPA technical publications on the industry, and consultation with qualified personnel. Most of the information on waste water volumes and characteristics, however, was obtained from RAPP applications and from an on-site sampling program carried out during the preparation of this document. Some additionnal information was derived from a questionnaire distributed through the Asbestos Information Association, North America.

Twelve corporations at 51 locations in the United States manufacture products which are covered by this document. At thirteen locations, two or more products are made, resulting in a total of 68 manufacturing facilities having one or two production lines each. RAPP applications were available and used for 37 of these facilities. Except for two locations, these applications covered all of the plants in the industry that discharge waste waters to navigable streams. The applications provided data on the characteristics of intake and effluent waters, water usage, waste water treatment provided, daily production, and raw materials used.

The program of visiting and sampling at ten selected manufacturing plants was designed to verify the available data on waste water characteristics, develop flow diagrams, observe water conservation practices, and define existing treatment techniques and associated cost. All of the information about untreated and partially treated waste waters was obtained from the sampling program.

The number of known manufacturing facilities in each product subcategory and the means of waste water disposal are presented in Table 1. Also shown are the number visited and sampled by the contractor. It should be noted that five of the facilities that achieve zero discharge by comple recycle are at one location and are served by a common treatment unit.

A voluntary questionnaire was distributed to its membership by the Asbestos Information Association, North America. It outlined the types of information desired, if available. Since most of the companies in the industry were contacted directly by the EPA contractor, the purpose of distributing the questionnaire was to provide the remaining plants an opportunity to participate in the study. A copy of the questionnaire is presented on the following pages.

TABLE 1

MANUFACTURING FACILITIES IN THE
ASBESTOS MANUFACTURING INDUSTRY

	Asbestos-Cement Pipe	Asbestos-Cement Sheet	Asbestos Paper	Asbestos Millboard	Asbestos Roofing	Asbestos Floor Tile
Discharge:						
to steam	11	7	7	3	5	6
to municipal system	1	4	4	2	3	7
non-recycle	1	2	1	2	1	0
non-evap'n.	1	0	0	0	0	0
Total	14	13	12	7	9	13
RAPP Application	11	7	5	3	5	6
Visted	4	3	3	4	1	2
Sampled	3	2	2	2	1	1

QUESTIONNAIRE FORM

I GENERAL

A. Company name

B. Address

C. Contact - company personnel

D. Telephone number

E. Contact-plant personnel

F. Address of plant reporting

G. Plant telephone number

II MANUFACTURING PROCESS CHARACTERIZATION (Separate sheet for each product)

A. Product

B. Manufacturing process

C. Major ingredients and general formulation

D. Production rate

E. Operating Schedule

F. Number of employees

III PROCESS WASTE WATERS

A. Volumes and sources

B. How and why water is used in the process?

C. Does the source, volume, or character of waste water vary depending on the type or quality of product?

D. How do waste water characteristics change during start-up and shutdown as compared to normal operation?

E. Quantity and point of application of acid, pigment, or other special chemicals used that might enter the waste water stream.

F. Information, if available, on untreated waste water:

1. pH
2. Alkalinity
3. Total solids
4. Suspended solids
5. Dissolved solids
6. Temperature
7. BOD_5
8. COD
9. Phosphorus

G. Waste water treatment

1. Waste water sources and volumes to treatment facility
2. Reason for treatment
3. Describe treatment system and operation
4. Type and quantity of chemicals used, if any
5. Available information on treated waste water quality (same items as Section III F, above)

H. Waste water recycle

1. Is any waste water recycled presently?
2. Can waste water be recycled?

I In-plant methods of water conservation and/or waste reduction

J. Identify any air pollution, noise or solid wastes resulting from treatment or other control methods. How is the solid waste disposed of?

K. Cost information (Related to water pollution control)

1. Treatment plant and/or equipment

2. Operation (Personnel, maintenance,etc.)

3. Power

4. Estimated equipment life

L. Water pollution control methods being considered for future application

IV Other waste water, e.g., boiler blowdown, spent cooling water, water treatment residues, etc., same informtion as in Section III above

V Water requirements

1. Volume and sources

2. Uses (including volume)

a. Process

b. Cooling

c. Washing

d. Dust suppression

e. Plant cleanup

f. Sanitary (if available)

g. Boilers

h. Other

3. Available information on raw water quality

4. Pretreatment provided

a. Volume treated

b. Reason for treatment

c. Describe treatment system and operation

d. Type and quantity of chemicals used

e. Available information on treated water quality

GENERAL DESCRIPTION OF THE INDUSTRY

Although known as a curiosity since biblical times, asbestos was not used in manufacturing until the latter half of the 19th century. By the early years of the 20th century, much of the basic technology had been developed, and the industry has grown in this country since about that time. Canada is the world's largest producer of asbestos, with the USSR and a few African countries as major suppliers. Mines in four states, Arizona, California, North Carolina, and Vermont provide a relatively small proportion of the world's supply.

Asbestos is normally combined with other materials in manufactured products, and consequently, it loses its identity. It is a natural mineral fiber which is very strong and flexible and resistant to breakdown under adverse conditions; especially high temperatures. One or more of these properties are exploited in the various manufactured products that contain asbestos.

Asbestos is actually a group name that refers to several serpentine minerals having different chemical compositions but similar characteristics. The most widely used variety is chrysotile. Asbestos fibers are graded on the basis of length, with the longest grade priced 10 to 20 times higher than the short grades. The shorter grades are normally used in the products covered in this document.

On a world-wide basis, asbestos-cement products materials and pipe currently consume about 70 percent of the asbestos mined. In the United States in 1971, the consumption pattern was reported to be:

Asbestos-cement products	25%
Floor tile	18
Paper and felts	14
Friction products	10
Textiles	3
Packing and gaskets	3
Sprayed insulation	2
Miscellaneous uses	25

These figures do not accurately reflect the production levels of these products because the asbestos content varies from about 10 to almost 100 percent among the different manufactured products.

This document covers the first three groups in the above list. These groups were selected because they represent a major segment of the industry; water is an ingredient in the manufacturing process, with two exceptions; and they were regarded as the most important sources of water pollutants in this industrial category.

Asbestos-Cement Products (A/C Pipe and A/C Sheet)

Asbestos fibers in asbestos-cement products serve the same role as steel rods in reinforced concrete, i.e., they add strength. Portland cement and silica are also major ingredients of these products.

Asbestos-cement pipe is manufactured for use in high pressure and low pressure applications in diameters from 7.6 to 91.5 cm (3 to 36 inches) and in lengths up to 4 meters (13 feet). It is used to carry waste waters, water supplies, and other fluids and in venting and duct systems. Asbestos-cement flat and corrugated sheets are used for exterior sheathing, siding and roofing, interior partitions, packing in cooling towers, laboratory bench tops, and many other specialty applications.

Asbestos Floor Tile

The shortest grades of asbestos fibers are used in vinyl and asphalt floor tile manufacture. The fibers are used to provide dimensional stability. Today, vinyl asbestos floor tile accounts for most of the asbestos used in this category, with asphalt tile serving some special applications and where darker shades are permissible.

Asbestos Papers and Millboard

Asbestos papers have a high fiber content and are manufactured with a variety of binders and other additives for many applications. These include pipe coverings, gaskets, thermal linings in heaters and ovens, and wicks. Heavier papers are commonly used for roofing materials and shingles. Millboard is a heavier, stiffer form of paper that includes clays, cement, or other additives. It is used for stove lining, filament supports in toasters, and several other high temperature applications.

MANUFACTURING LOCATIONS

The locations of the plants that manufacture the products covered in this document are listed in Table 2. This listing includes all the plants as reported by the major manufacturers. All of the available known information from the plants at these locations was collected for use in this study. At several plants, no information about waste-water volumes or characteristics was known.

At most of the plants, only one asbestos product is manufactured. There are three reported locations that manufacture more than one category of asbestos products in the same plant in a manner that results in a combined waste water flow. Since the waste waters from all the asbestos products categories, except roofing and floor tile, have many common characteristics, they are generally treatable by the same types of control technology. Consequently,

TABLE 2

LOCATIONS OF ASBESTOS MANUFACTURING PLANTS

State	Location	Company	Products
Alabama	Ragland	Cement Asbestos Products Co.	A-C Pipe
	Mobile	GAF Corporation	A-C Sheet
Arkansas	Van Buren	Cement Asbestos Products Co.	A-C Pipe
California	La Mirada	American Biltrite Rubber	Floor Tile
	South Gate	Armstrong Cork Company	Floor Tile
	Riverside	Certain-Teed Products Corp.	A-C Pipe
	Santa Clara	Certain-Teed Products Corp.	A-C Pipe
	Los Angeles	The Flintkote Company	Floor Tile
	Long Beach	GAF Corporation	Floor Tile
	Long Beach	Johns-Manville	A-C Pipe
	Los Angeles	Johns-Manville	Roofing
	Pittsburg	Johns-Manville	A-C Sheet, Paper
	Stockton	Johns-Manville	A-C Pipe
Florida	Green Cove Springs	Johns-Manville	A-C Pipe
Georgia	Savannah	Johns-Manville	Roofing
Illinois	Kankakee	Armstrong Cork Company	Floor Tile
	Chicago	The Flintkote Company	Floor Tile
	Joliet	GAF Corporation	Floor Tile

TABLE 2 (contd)

LOCATIONS OF ASBESTOS MANUFACTURING PLANTS

State	Location	Company	Products
Illinois (contd)	Waukegan	Johns-Manville	A-C Pipe, A-C Sheet, Paper, Millboard, Roofing
Louisiana	New Orleans	The Flintkote Company	Floor Tile
	Marrero	Johns-Manville	A-C Sheet, Roofing
	New Orleans	National Gypsum Company	A-C Sheet
Massachusetts	Millis	GAF Corporation	Roofing
	Billerica	Johns-Manville	Millboard
Mississippi	Jackson	Armstrong Cork Company	Floor Tile
Missouri	St. Louis	Certain-Teed Products Corp.	A-C Pipe
	St. Louis	GAF Corporation	A-C Sheet
New Hampshire	Nashua	Johns-Manville	A-C Sheet
	Tilton	Johns-Manville	Paper, Millboard
New Jersey	Linden	Celotex Corporation	Paper
	South Bound Brook	GAF Corporation	A-C Sheet, Roofing

TABLE 2 (contd)

LOCATIONS OF ASBESTOS MANUFACTURING PLANTS

State	Location	Company	Products
New Jersey (contd)	Manville	Johns-Manville	A-C Pipe, A-C Sheet, Paper, Roofing
	Millington	National Gypsum Company	A-C Sheet
New York	Fulton	Armstrong Cork Company	Paper
	Vails Gate	GAF Corporation	Floor Tile
	Brooklyn	Kentile Floors, Inc.	Floor Tile
Ohio	Cincinnati	Celotex Corporation	A-C Sheet, Paper, Millboard
	Ravenna	The Flintkote Company	A-C Pipe
	Hamilton	Nicolet Industries, Inc.	Paper
Pennsylvania	Lancaster	Armstrong Cork Company	Floor Tile
	Ambler	Certain-Teed Products Corp.	A-C Pipe
	Erie	GAF Corporation	Paper, Millboard
	Erie	GAF Corporation	Roofing
	Whitehall	GAF Corporation	Paper
	Ambler	Nicolet Industries, Inc.	A-C Sheet, Millboard
	Norristown	Nicolet Industries, Inc.	Paper, Millboard

TABLE 2 (contd)

LOCATIONS OF ASBESTOS MANUFACTURING PLANTS

State	Location	Company	Products
Texas	Hillsboro	Certain-Teed Products Corp.	A-C Pipe
	Houston	GAF Corporation	Floor Tile
	Denison	Johns-Manville	A-C Pipe
	Fort Worth	Johns-Manville	Paper, Roofing
Puerto Rico	Ponce	Boringuen Asbestos Cement Corp.	A-C Sheet

the combined waste waters from the manufacture of multiple asbestos products do not present significant additional problems in control.

Of more significance from a water pollution control point of view is the manufacture of non-asbestos products with confluent waste streams at some of the locations. The most common combinations are the manufacture of plastic pipe at asbestos-cement pipe plants and the manufacture of "organic" (cellulose fiber) paper at asbestos paper plants. Plastic pipe manufacture is not likely to result in the discharge of significant pollution other than waste heat. Organic paper manufacturing waste waters, however, are significantly stronger and of different character than those from asbestos paper production. The raw materials are often paperstock (salvaged paper) as well as virgin pulp and the wastes are highly colored, turbid, and high in oxygen demand.

MANUFACTURING PROCESSES

With the exception of roofing and floor tile manufacture, there is a basic similarity in the methods of producing the various asbestos products. The asbestos fibers and other raw materials are first slurried with water and then formed into single or multi-layered sheets as most of the water is removed. The manufacturing process always incorporates the use of save-alls (settling tanks of various shapes) through which process waste waters are usually routed. Water and solids are recovered and reused from the save-all, and excess overflow and underflow constitute the process waste streams. In all of these product categories, water serves both as an ingredient and a means of conveying the raw materials tc and through the forming steps.

ASBESTOS-CEMENT PRODUCTS (A/C Pipe and A/C Sheet)

The largest single use category of asbestos fibers in the United States is the manufacture of asbestos-cement products. The pipe segment is the largest component of this product category.

Raw Materials

Asbestos-cement products contain from 10 to 70 percent asbestos by weight, usually of the chrysotile variety. Crocidolite and other types are used to a limited extent depending upon the properties required in the product. Portland cement content varies from 25 to 70 percent. Consistent cement quality is very important since variations in the chemical content or fineness of the grind can affect production techniques and final product strength. The remaining raw material, from 5 to 35 percent, is finely ground silica. Some asbestos-cement pipe plants have facilities for grinding silica as an integral part of their operations. Finely ground solids from damaged pipe or sheet trimmings are used by some plants as filler material. A maximum of 6 percent filler can be used in some products before strength is affected.

The interwoven structure formed by the asbestos fibers in asbestos-cement products functions as a reinforcing medium by imparting increased tensile strength to the cement. As a result, there is a 70 to 80 percent decrease in the weight of the product required to attain a given structural strength. It is important that the asbestos be embedded in the product in a completely fiberized or willowed form, and the necessary fiber conditioning is frequently carried out prior to mixing the fiber with the cement and silica. In some cases, however, this fiber opening is accomplished while the wet mixture is agitated by a pulp beater, or hollander.

Manufacture

Asbestos-cement sheet products are manufactured by the dry process, the wet process, or the wet mechanical process. Figures 1 through 3 illustrate the sequence of steps in each of these manufacturing processes with the sources of wastes indicated. Products having irregular shapes are formed by molding processes which account for only a very limited production today. Extrusion processes are not widely used in the United States.

Dry Process-

In the dry process (Figure 1), which is suited to the manufacture of shingles and other sheet products, a uniform thickness of the mixture of dry materials is distributed onto a conveyor belt, sprayed with water, and then compressed against rolls to the desired thickness and density. Rotary cutters divide the moving sheet into shingles or sheets which are subsequently removed from the conveyor for curing. The major source of process waste water in this process is the water used to spray clean the empty belt as it returns.

Wet Process-

The wet process (Figure 2) produces dense sheets, flat or corrugated, by introducing a slurry into a mold chamber and then compressing the mixture to force out the excess water. A setting and hardening period of 24 to 48 hours precedes the curing operation. The large, thick monolithic sheets used for laboratory bench tops are manufactured by this process. The grinding operations used to finish the sheet surfaces produce a large quantity of dust which may be discharged with the process waste waters. This affords a means of reducing and controlling air emissions.

Wet Mechanical Process-

The wet mechanical process, which is also used for the manufacture of asbestos-cement pipe (Figure 4), is similar in

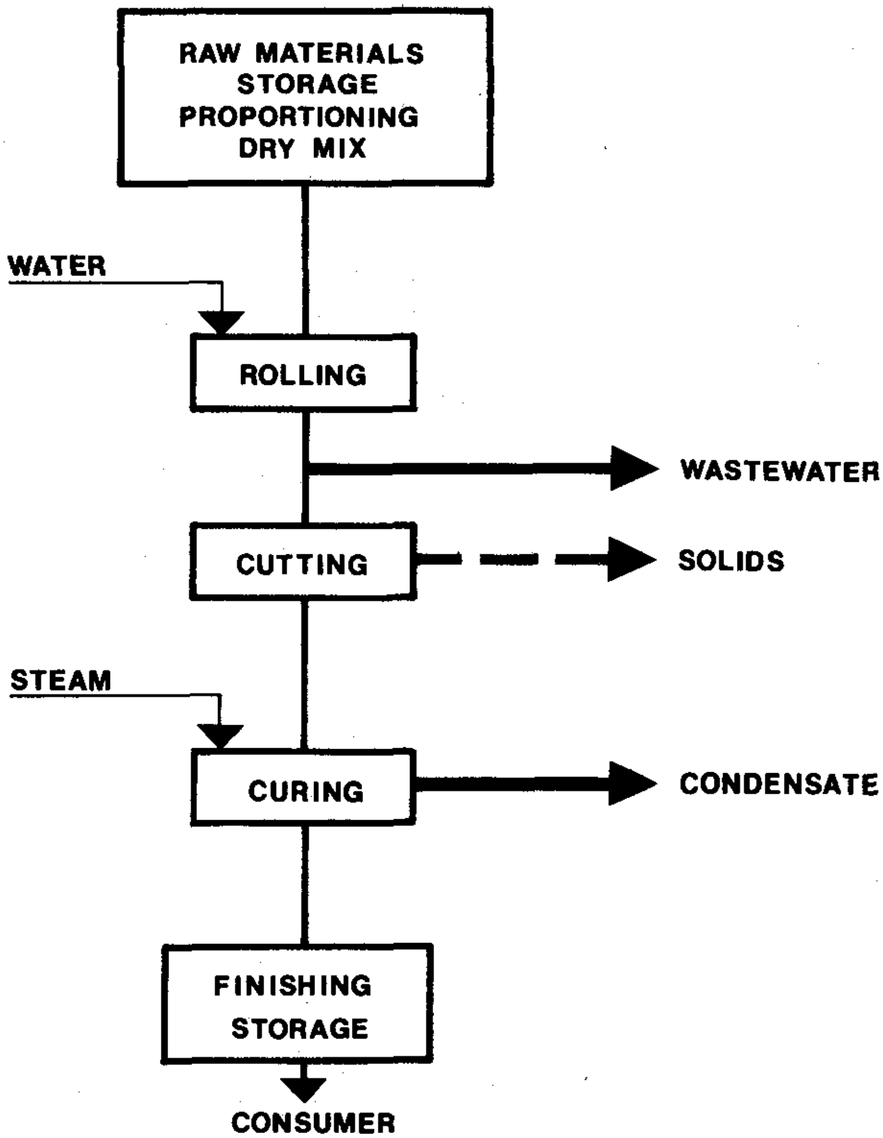


Figure 1 - Asbestos-Cement Sheet Manufacturing Operations, Dry Process

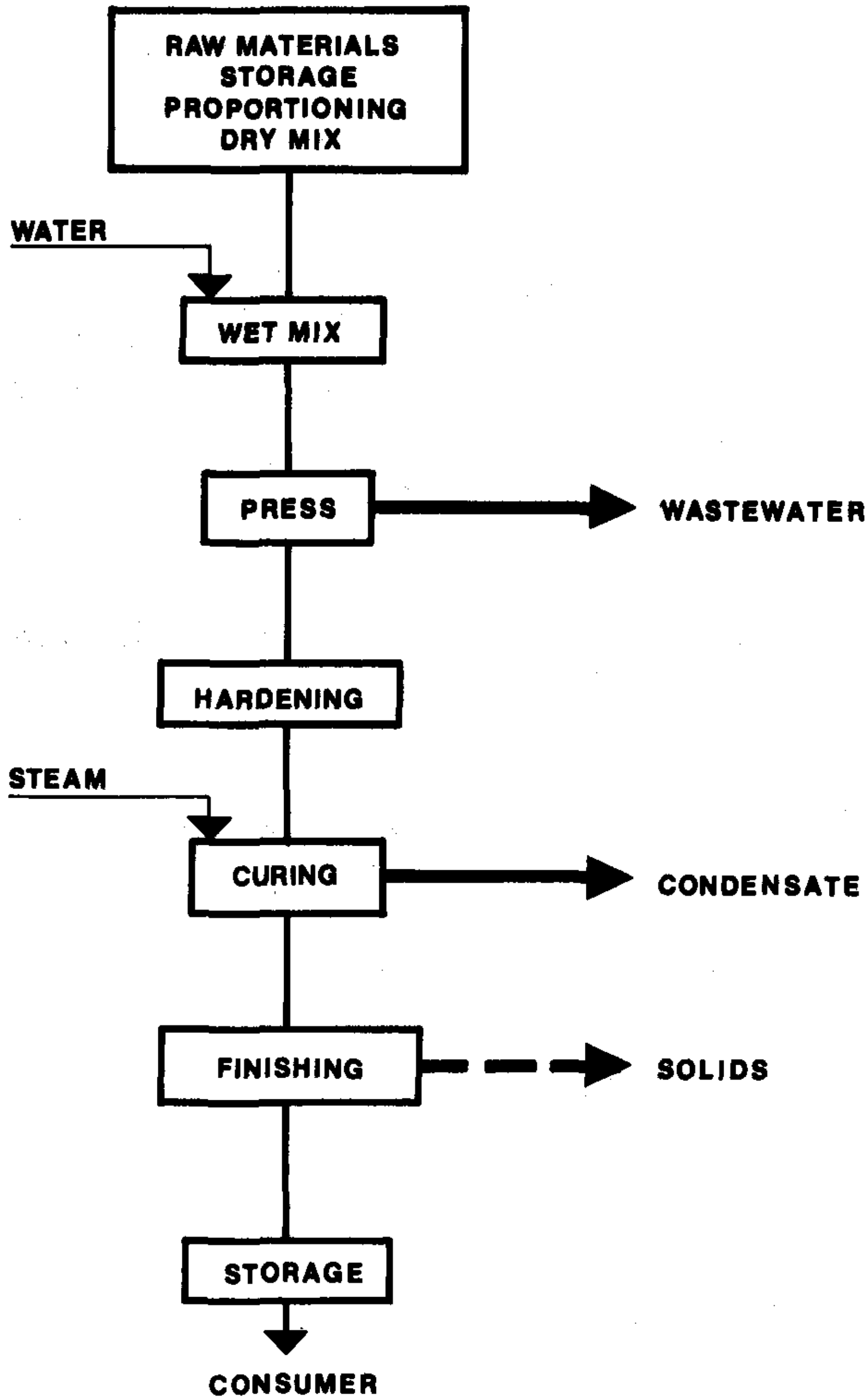


Figure 2 - Asbestos-Cement Sheet Manufacturing Operations, Wet Process

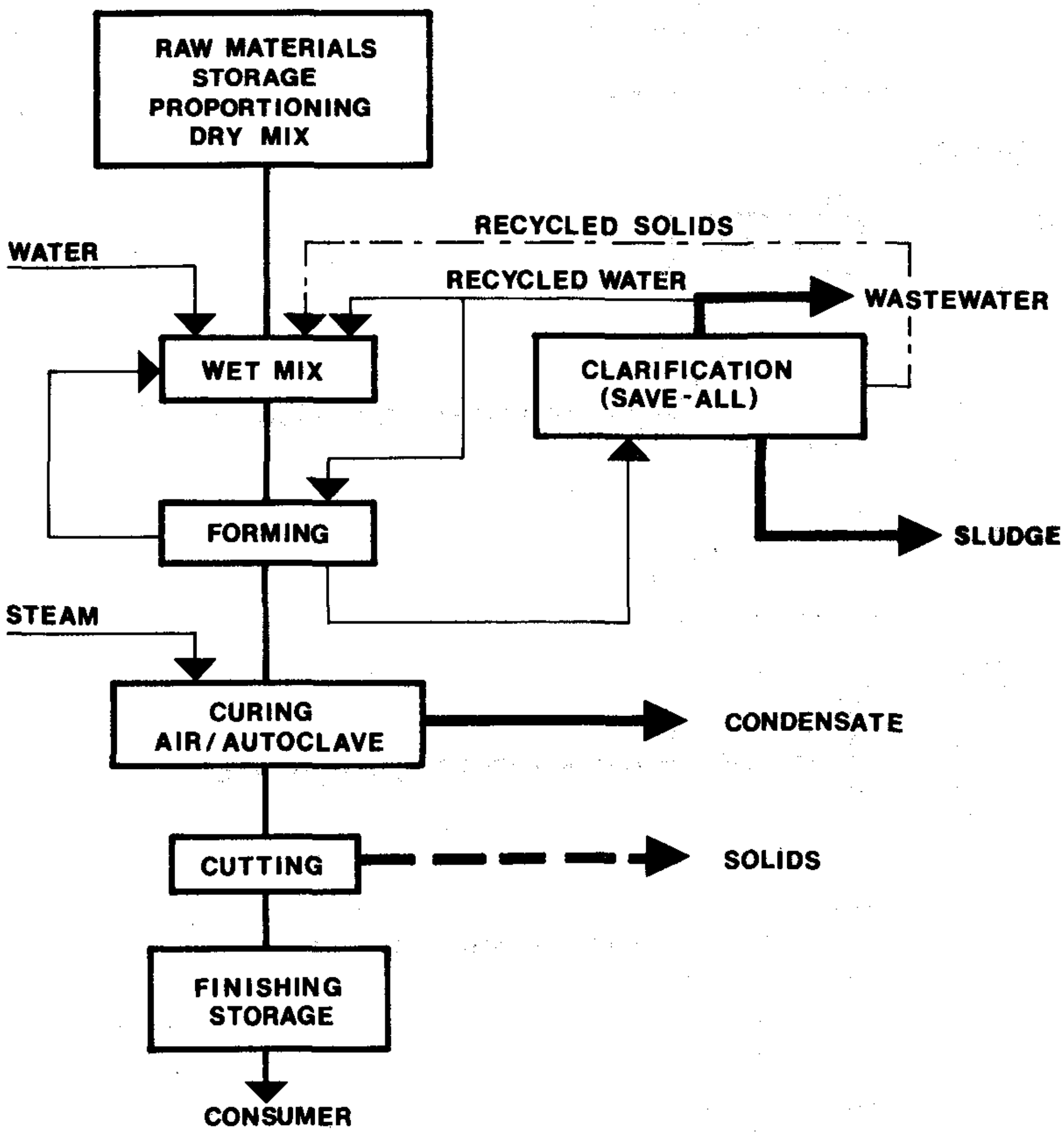


Figure 3 - Asbestos-Cement Sheet Manufacturing Operations, Wet Mechanical Process

principle to some papermaking processes. The willowed asbestos fiber is conveyed to a dry mixer where it is blended with the cement, silica, and filler solids. After thorough blending of the raw materials, the mixture is transferred to a wet mixer or beater. Underflow solids and water from the save-all are added to form a slurry containing about 97 percent water. After thorough mixing, the slurry is pumped to the cylinder vats for deposition onto one or more horizontal screen cylinders. The circumferential surface of each cylinder is a fine wire mesh screen that allows water to be removed from the underside of the slurry layer picked up by the cylinder. The resulting layer of asbestos-cement material is usually from 0.02 to 0.10 inch in thickness. The layer from each cylinder is transferred to an endless felt conveyor to build up a single mat for further processing. A vacuum box removes additional water from the mat prior to its transfer to mandrel or accumulator roll. This winds the mat into sheet or pipe stock of the desired thickness. Pressure rollers bond the mat to the stock already deposited on the mandrel or roll and remove excess water. Pipe sections are removed from the mandrel, air cured, steam cured in an autoclave, and then machined on each end.

In the manufacture of sheet products by the wet mechanical process, the layer of asbestos-cement on the accumulator roll is periodically cut across the roll and peeled away to form a sheet. The sheet is either passed through a pair of press rollers to shape the surface and cut the sheet into shingles, formed into corrugated sheet, or placed onto a flat surface for curing.

The asbestos-containing water removed from the slurry or mat is recycled to the process. Very little asbestos is lost from the manufacturing process.

<u>Cleaning</u>

The cylinder screen and felt conveyor must be kept clean to insure proper operation. Cylinder showers spray water on the wire surface after the mat has been removed by the felt. Any cement or fiber particles are washed out of the holes in the screen to prevent "blinding."

The cylinders, mandrels, and accumulator rolls are occasionally washed in acetic or hydrochloric acid to remove cement deposits. This cleaning may be carried out while the machine is in operation or the component, especially cylinder screens, may be removed to a separate acid washing facility.

The felt washing showers are a row of high-pressure nozzles that, with the aid of a "whipper," wash fiber out of the felt after the mat of fiber has been picked up by the mandrel or accumulator roll. Fiber build-up in the felt can prevent vacuum boxes from removing excess water from the mat.

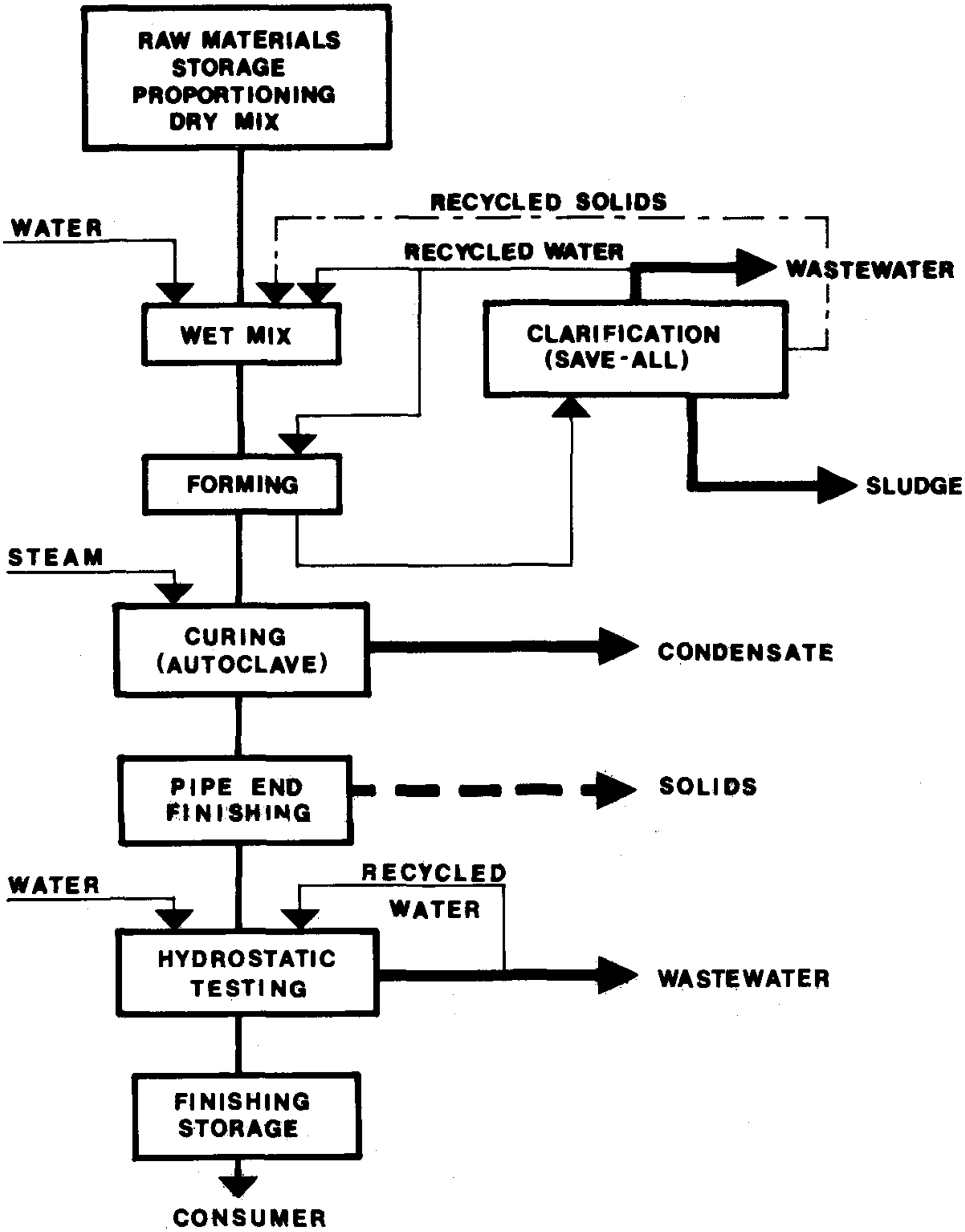


Figure 4 - Asbestos-Cement Pipe Manufacturing Operations,
Wet Mechanical Process

In-Plant Recycling

Asbestos-cement product plants recycle the majority of their water as a means of recovering all usable solids. All water serving as the carrying agent, 80 to 90 percent of the water in the process, passes through a save-all after leaving the machine vat. Solids that settle out and concentrate near the bottom of the save-all are pumped to the wet mixer to become part of a new slurry. Much of the clarified overflow from the save-all can be used for showers, dilution, and various other uses depending upon the efficiency of the save-all.

The save-all overflow may be discharged from the plant or may be treated and returned to the plant for whatever uses its quality justifies. This may include water for wet saws, vacuum pump seals, cooling, hydrotesting, or makeup water for plant startup. If any of these uses cannot be served by treated water, fresh water must be used since the quality and temperature of save-all overflow water is rarely acceptable without additional clarification.

At most asbestos-cement product plants, part of the products that are damaged or unacceptable for other reason are crushed, ground, and used as filler in new products. The remainder is crushed and added to a refuse pile or landfill.

Asbestos-cement sheet plants trim the edges of the wet sheets as they come off the accumulator roll. The trimmings are immediately returned to the wet mixer. At this stage, the cement has not begun to react and the trimmings can be an active part of the new slurry.

Operating Schedule

Asbestos-cement pipe plants typically operate 24 hours a day and five or six days a week. Sheet plants may operate two shifts a day rather than three depending upon market demand.

ASBESTOS PAPER

Asbestos paper has a great variety of uses and ingredient formulas vary widely depending upon the intended use of the paper. The purchaser frequently specifies the exact formula to insure that the paper has the desired qualities.

Raw Materials

Asbestos paper usually contains from 70 to 90 percent asbestos fiber by weight, usually the short grades. A mixture of the various varieties of asbestos fiber is used with chrysotile as the principal type. The binder content of asbestos paper accounts for 3 to 15 percent of its weight. The content and type varies with the desired properties and intended applications of the paper. Typical binders are starch, glue, cement, gypsum, and several natural and synthetic elastomers.

Asbestos paper used for roofing paper, pipe wrapping, and insulation usually contains between 5 and 10 percent kraft fiber. Mineral wool, fiberglass, and a wide variety of other constituents are included to provide special properties and may represent as much as 15 percent of the weight.

Manufacture

Asbestos paper is manufactured on machines of the Fourdrinier and cylinder types that are similar to those which produce cellulose (organic) paper. The cylinder machine is more widely employed in the industry today. The overall manufacturing process is shown in Figure 5 with waste sources indicated.

The mixing operation combines the asbestos fibers with the binders and any other minor ingredients. A pulp beater or hollander mixes the fibers and binder with water into a stock which typically contains about three percent fiber. Upon leaving the stock chest, the stock is diluted to as little as one-half percent fiber in the discharge chest. The amount of dilution depends upon the quality of the paper to be produced.

The discharge chest of a Fourdrinier paper machine deposits a thin and uniform layer of stock onto an endless moving wire screen through which a major portion of the water is drawn by suction boxes or rolls adjacent to the sheet of paper. The sheet is then transferred onto an endless moving felt and pressed between pairs of rolls to bring the paper to approximately 60 percent dryness. Subsequently, the continuous sheet of paper passes over heated rolls, while supported on a second felt, to effect further drying. This is followed by calendering, to produce a smooth surface, and winding of the paper onto a spindle.

The operation of a cylinder paper-making machine includes a mixing operation for stock as indicated for the Fourdrinier machine. Cylinder-type paper machines usually have four to eight cylinders instead of two as in most asbestos-cement pipe machines.

The stock is pumped to the cylinder vats of the machine. Each vat contains a large screen-surfaced cylinder extending the full length of the vat. The stock slurry flows through the screen depositing a thin layer of fiber on the surface of the rotating cylinder before flowing out through the ends of the cylinder. The layer of fiber is then transferred to a carrier felt moving across the top of the rotating cylinders. The layers picked up from the cylinders are pressed together becoming a single homogeneous sheet as the felt passes over each successive cylinder.

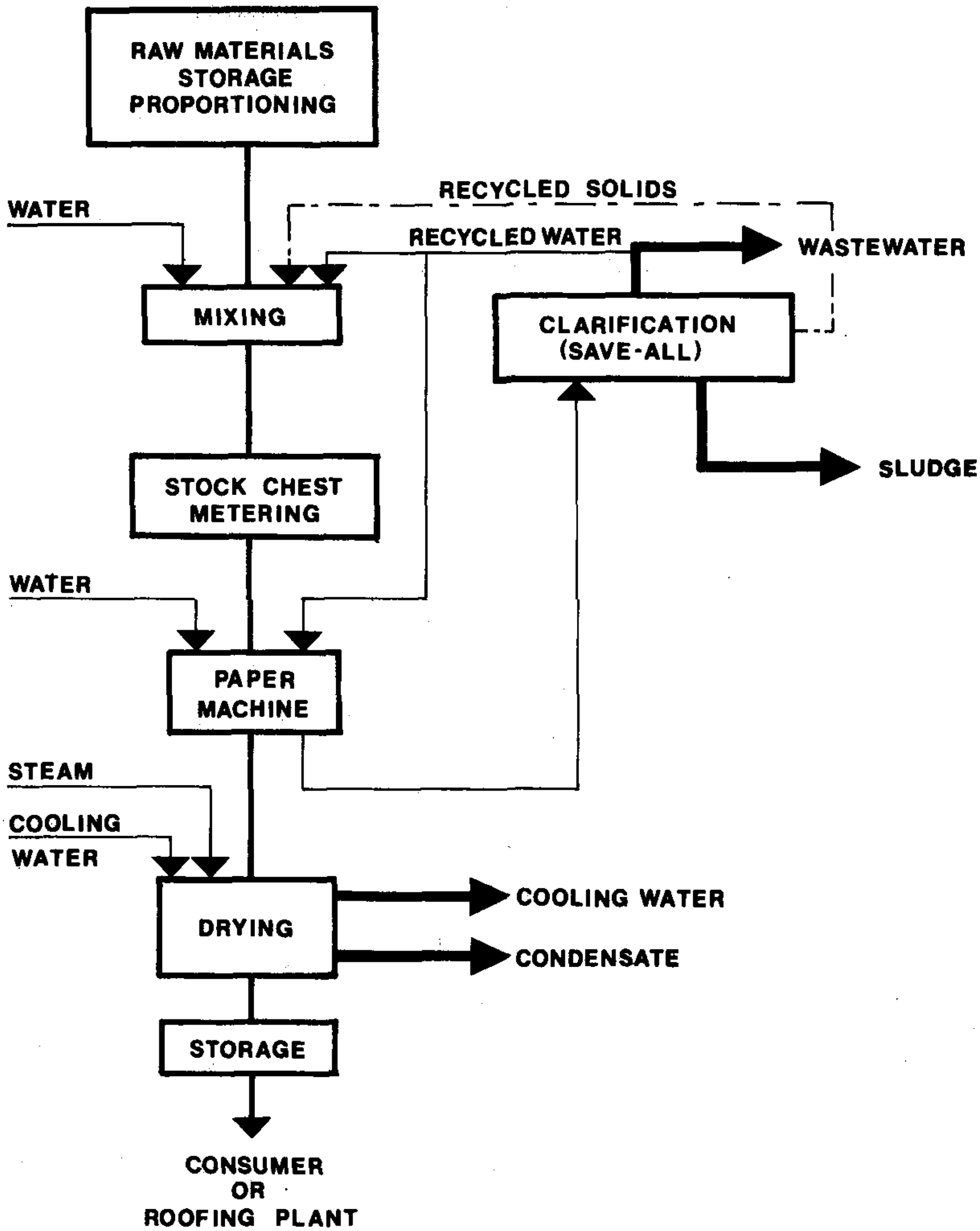


Figure 5 - Asbestos Paper Manufacturing Operations

Vacuum boxes draw water out and pressure rolls squeeze water out of the sheet and felt until the sheet is dry enough to be removed from the felt. After leaving the felt, the sheet is dried on steam rolls and in ovens. The paper is then calendered to produce a smooth surface and wound onto a spindle.

The width of the paper sheet is regulated by the deckles, a row of nozzles located at each end of the cylinder screens. The deckles spray water on the screen at the edge of the sheet and wash off excess fiber.

Cleaning

The cylinder showers are a row of nozzles that spray water on the surface of the cylinder screens after the paper stock mat has been removed by the felt. They wash any remaining fiber and binder out of the holes in the screens to prevent a build-up of fiber from "blinding" the screen and stopping the flow of water required to deposit a layer of fiber on the surface of the cylinder.

The felt washing operations are carried out using high pressure nozzles as in asbestos-cement pipe manufacture.

The asbestos-containing water, or "white water," which is removed from the stock prior to passage across the heated drying rolls is recycled to the process.

Water Usage

Water serves three basic purposes in the asbestos paper manufacturing process: ingredient carrier, binder wetting agent, and heat transfer fluid. Other uses include water for showers, deckles, pump seals, plant make-up, boiler make-up, and cooling.

Fresh water enters the system as boiler make-up, process make-up, pump seal water, and shower water. Boiler make-up water provides steam for heating the paper stock and drying the finished paper. The steam used to heat the stock slurry becomes a part of the slurry and must be replaced. Condensate from the drying rolls is recovered and returned to the boiler. Fresh water must be used to cool the dried paper unless a cooling tower is available. Save-all overflow and other plant water is usually too hot for such purposes. Large quantities of fresh water are required during plant start-up to fill the system. This occurs infrequently, however. Small quantities of water are required continuously to replace that which evaporates during drying and that which becomes a permanent part of the paper. The characteristics of some paper products are such that fresh water must be used for part, or all, of the beater make-up water.

Cylinder and felt washing showers usually require fresh water because save-all overflow water is rarely clean enough to be used in the high pressure shower nozzles without causing plugging.

Fresh water is used for the pump shaft seal water because the presence of dirt in the seal water will cause plugging and can cause scoring of the shaft. Although the cooling water and part of the pump seal water may be discharged from the plant after a single use, most of the fresh water introduced into the plant enters the ingredient carrying system, and, therefore, the paper machine save-all loop.

In-Plant Recycling

The majority of the water in a paper plant serves as an ingredient carrier and continually circulates in a loop through the paper machine and the save-all. All water flowing out of the cylinder screen and that drawn by vacuum out of the wet paper sheet is pumped to the save-all. The solids settle to the bottom of the save-all and are pumped to the stock chest of the beater. Occasionally, the solids from the save-all must be discharged from the plant due to a product change, rapid setup of the binder, or a plant shutdown. Save-all overflow water is used for beater makeup, dilution, deckle water, and occasionally shower water.

Excess overflow water must be discharged from the plant or sent to a waste water treatment facility for additional treatment before it can be reused.

Trimmings from the edge of the paper, defective paper, and other waste paper can usually be returned to the beater and repulped for recycling.

Operating Schedule

Asbestos paper manufacturing plants typically operate 24 hours a day and 7 days a week.

MILLBOARD

Asbestos millboard is considered by some to be a very heavy paper and is in fact very much like thick cardboard in texture and structural qualities. It can easily be cut or drilled and can be nailed or screwed to a supporting structure.

Raw Materials

Millboard formulas vary widely depending upon the intended use of the product. Purchasers frequently specify the ingredients and composition of the millboard to insure that the product meets their particular requirements. Asbestos content ranges between 60 and 95 percent with the higher content for products that will be in close or direct contact with high temperature materials. Portland cement and starch are the most common binders used and represent 5 to 40 percent of the product. Clay, lime, mineral wool, and several other materials are frequently used as fill material or to provide special qualities. Water is also an important ingredient in millboard.

Manufacture

The manufacturing steps in asbestos millboard production with waste sources indicated are shown in Figure 6. Millboard is produced on small cylinder-type machines similar to those used for making asbestos-cement pipe. The machines are equipped with one or two cylinder screens, conveying felt, pressure rolls, and a cylinder mold. After the ingredients are mixed in a beater, the slurry is transferred to a stirring vat or stock chest from which it is diluted and pumped to the cylinder vats of the millboard machines. Each cylinder vat contains a large screen surfaced cylinder extending the full length of the vat. The slurry flows through the screen depositing a mat of fiber on the surface of the rotating cylinder before flowing out through the ends of the cylinder. The mat of fiber is then transferred to a carrier felt moving across the top of the rotating cylinder. On two-cylinder machines, the mats from the first and second cylinders are pressed together becoming a single homogeneous sheet as the felt picks up the mat of fiber from the second cylinder. Pressure rolls above the felt squeeze water from the mat as it is picked up from the cylinders. Some millboard machines have vacuum boxes adjacent to the felt that draw water out of the mat of fibers. Additional pressure rolls remove more water from the mat as it is wound onto the cylinder mold.

The cylinder mold is a drum about four feet wide and usually about four feet in diameter. As the carrier felt passes the cylinder mold, the mat is transferred to the cylinder because the adhesion to the wet cylinder surface is greater than the adhesion to the felt. The cylinder mold rotates, collecting successive layers of fiber until the desired thickness is obtained. The cylinder is then momentarily stopped and the mat of fiber cut along a notch on the surface of the cylinder parallel to the cylinder axis. The sheet of millboard is removed as the cylinder starts rotating to build up another sheet. The wet millboard, containing about 50 percent water, is air dried or moved into an autoclave or oven for rapid curing. Finished millboard usually contains 5 to 6 percent water.

Cleaning

The operation of the deckles, cylinder showers, and felt washing showers is basically the same as described previously for asbestos paper.

Water Usage

The uses and flow patterns of water in millboard manufacturing operations are very similar to those in asbestos paper making.

In-Plant Recycling

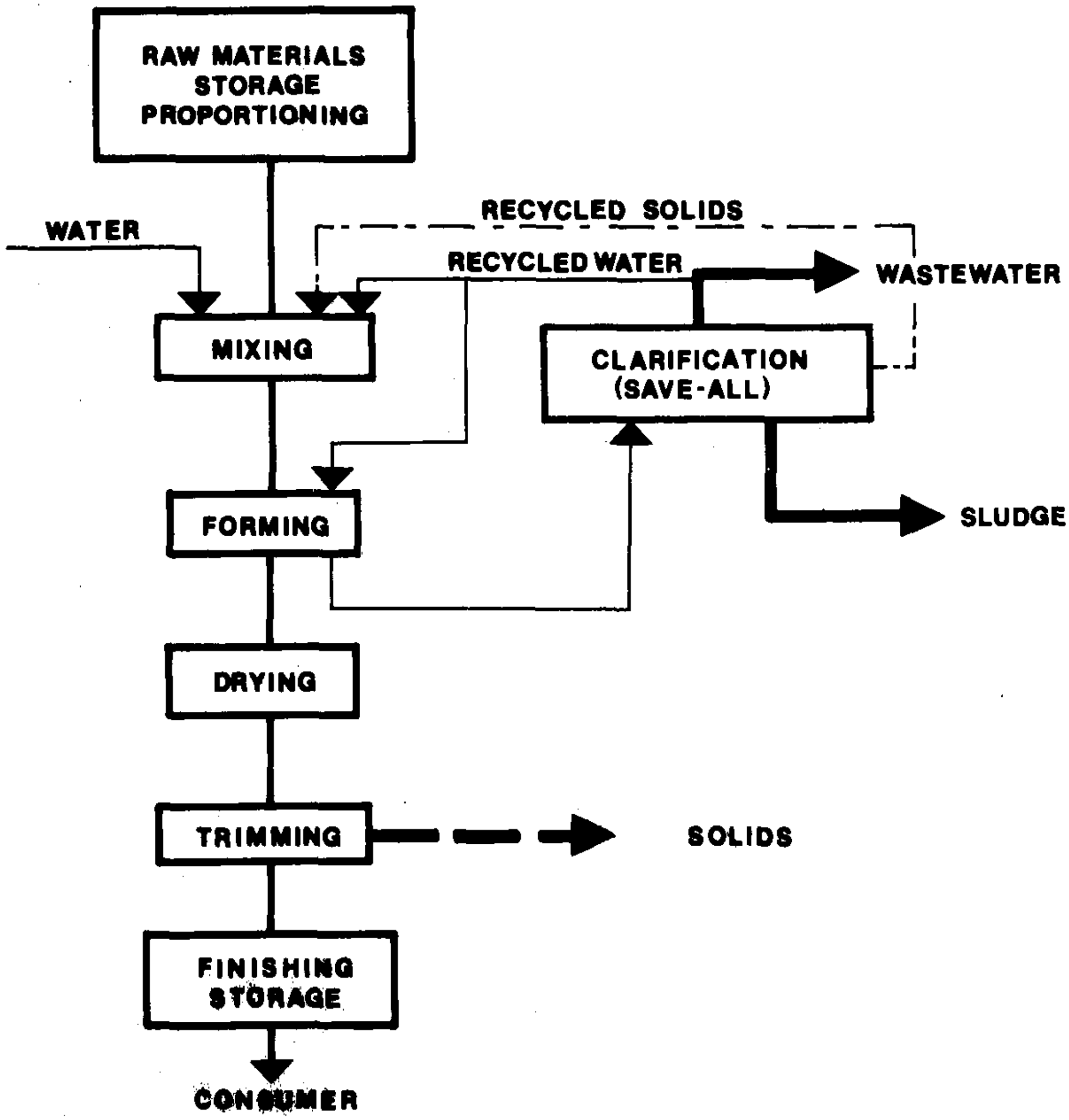


Figure 6 - Asbestos Millboard Manufacturing Operations

As with the asbestos products covered previously, most of the water in the millboard manufacturing process serves as an ingredient carrier and continually circulates in a loop through the millboard machine and the save-all. All water flowing out of the cylinder screen and that drawn by vacuum out of the wet millboard is pumped to the save-all. Solids that settle in the save-all are pumped to the stock chest or the beater. Save-all overflow water is used for beater make-up, dilution, deckle water, and occasionally shower water. Excess overflow water must be discharged from the plant or sent to a treatment facility for additional treatment before it can be reused.

When possible, trimmings from millboard sheets are returned to the beater and repulped for use in new millboard. Most millboards can accept from 5 to 10 percent reclaimed material.

Operating Schedule

A typical asbestos millboard plant operates two or three shifts per day and five or six days a week.

ASBESTOS ROOFING

Asbestos roofing is made by saturating heavy grades of asbestos paper with asphalt or coal tar with the subsequent application of various surface treatments. The stock paper may be single or multiple layered and usually contains mineral wool, kraft fibers, and starch as well as asbestos. Fiberglass filaments or strands of wire may be embedded between layers for reinforcement.

Manufacture

Figure 7 shows the major steps in the manufacture of asbestos roofing. Asbestos paper is pulled through a bath of hot coal tar or asphalt. After it is thoroughly saturated, the paper passes over a series of hot rollers to set the coal tar or asphalt in the paper. The paper then passes over cooling rollers that reduce the temperature of the paper and give it a smooth surface finish. At some plants, cooling water is sprayed directly on the surface of the saturated paper.

Roll roofing is coated with various materials to prevent adhesion between layers and then passed over a final series of cooling rollers. The roofing is then air dried and rolled up and packaged for marketing. The manufacture of asbestos roof shingles is similar from a waste water point of view.

Water Usage

Water is used in two ways in the production of roofing. It is converted to steam to heat the saturating baths and hot rollers and for cooling the hot paper after it has been saturated. Condensate from the saturating bath coils and the hot rollers is

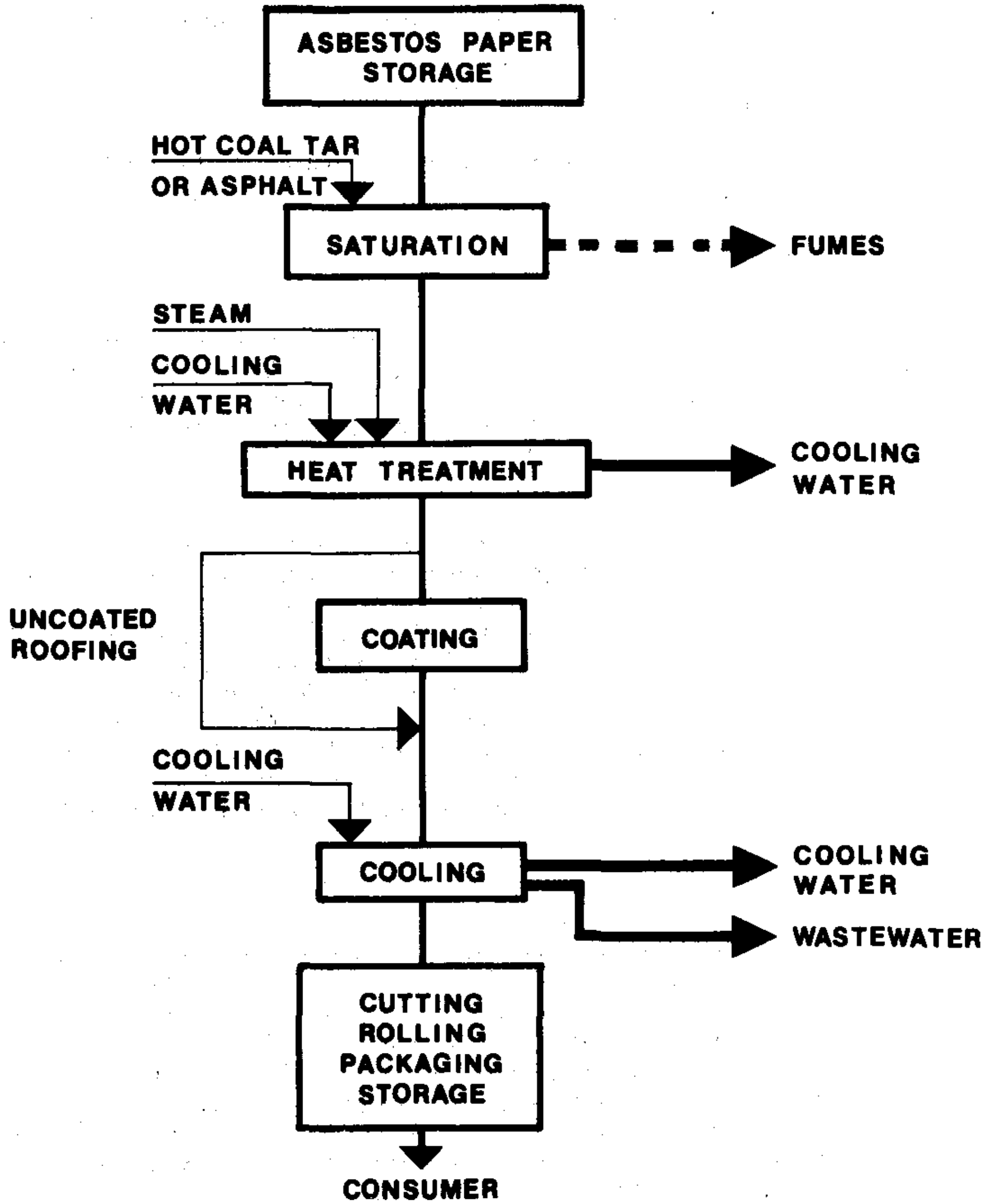


Figure 7 - Asbestos Roofing Manufacturing Operations

collected and returned to the boilers. Fresh make-up water in small quantities is required to replace boiler blowdown water, steam, and condensate that escapes through leaks. Cooling water is used once and discharged unless cooling towers or other means of cooling the water are available. The only process waste water associated with roofing manufacture is that originating in the spray cooling step. In many cases, this contaminated contact cooling water is discharged with the clean non-contact cooling water.

Operating Schedule

A typical roll roofing plant operates one or two shifts a day on a five-day per week schedule.

FLOOR TILE

Most floor tile manufactured today uses a vinyl resin, although some asphalt tile is still being produced. The manufacturing processes are very similar and the water pollution control aspects are almost identical for the two forms of tile.

Raw Materials

Ingredient formulas vary with the manufacturer and the type of tile being produced. The asbestos content ranges from 8 to 30 percent by weight and usually comprises very short fibers. Asbestos is included for its structural properties and it serves to maintain the dimensional stability of the tile. PVC resin serves as the binder and makes up 15 to 25 percent of the tile. Chemical stabilizers usually represent about 1 percent. Limestone and other fillers represent 55 to 70 percent of the weight. Pigment content usually averages about 5 percent, but may vary widely depending upon the materials required to produce the desired color.

Manufacture

The tile manufacturing process, shown in Figure 8, involves several steps; ingredient weighing, mixing, heating, decoration, calendering, cooling, waxing, stamping, inspecting, and packaging. The ingredients are weighed and mixed dry. Liquid constituents, if required, are then added and thoroughly blended into the batch. After mixing, the batch is heated to about 150 degrees C and fed into a mill where it is joined with the remainder of a previous batch for continuous processing through the rest of the manufacturing operation.

The mill consists of a series of hot rollers that squeeze the mass of raw tile material down to the desired thickness. During the milling operation, surface decoration in the form of small colored chips of tile (mottle) are sprinkled onto the surface of the raw tile sheet and pressed in to become a part of the sheet.

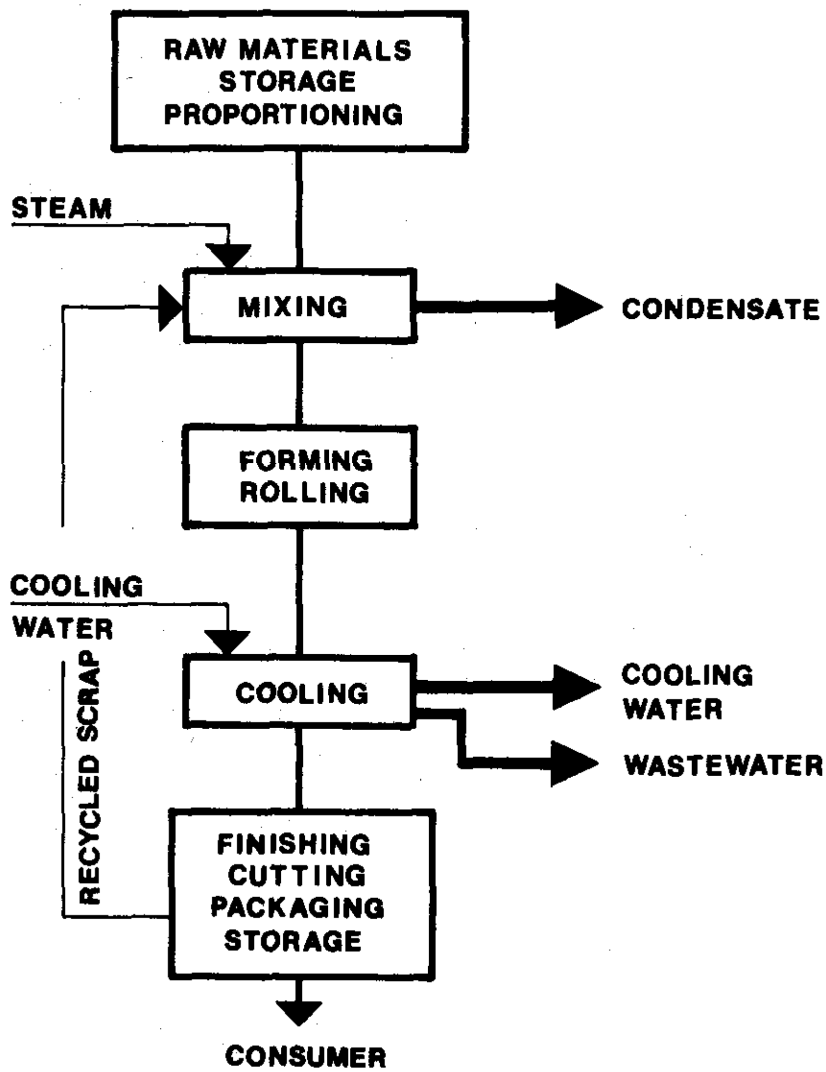


Figure 8 - Asbestos Floor Tile Manufacturing Operations

Some tile has a surface decoration embossed and inked into the tile surface during the rolling operation. This may be done before or after cooling. After milling, the tile passes through calenders until it reaches the required thickness and is ready for cooling. Tile cooling is accomplished in many ways and a given tile plant may use one or several methods. Water contact cooling in which the tile passes through a water bath or is sprayed with water is used by some plants. Others use non-contact cooling in which the rollers are filled with water. In some plants, the sheet of tile passes through a refrigeration unit where cold air is blown onto the tile surface. After cooling, the file is waxed, stamped into squares, inspected, and packaged. Trimmings and rejected tile squares are chopped up and reused.

Water Usage

Water serves only as a heat transfer fluid. It is used in the form of steam to heat the batches and the hot rollers. Fresh water is required for boiler make-up, but only in quantities large enough to replace leakage and boiler blowdown water. Non-contact cooling water remains clean and can be reused continually if cooling towers or water chillers are available to remove the heat picked up from the hot tile.

Make-up water is required only to replace water that leaks from the system. Direct contact cooling water from the cooling baths or sprays does not become contaminated from direct contact with the tile but may pick up dust or other materials. This water may be reused if facilities are available to clean the water and remove the heat. Fresh water is required to replace leakage and water that evaporates. Leakage from all sources collects dirt, oil, grease, wax, ink, glue, and other contaminants. This represents a serious potential for pollution if discharged to a receiving water.

Operating Schedule

Floor tile plants typically operate 24 hours a day on a five or six day per week schedule.

CURRENT STATUS OF THE INDUSTRY

There has long been concern about the industrial hygiene aspects of the dust and fiber emitted to the air in mining, processing, transportation, and manufacturing operations. This concern has recently been expanded to include the general public. Asbestos is among the first materials to be declared a hazardous air pollutant under the Clean Air Act amendments of 1970. Stringent regulations have also been promulgated to control exposure to workers in the industry.

The increased concern with the health effects of asbestos fibers in the air has produced changes that affect, to some degree, the water pollution control aspects of the industry. The principal change has been conversion of dry processes into wet processes and the use of water sprays to allay dust from mining operations and slag piles. This shifting is expected to continue in the future.

While there has been considerable interest and much research on the health effects of asbestos in air, there has been little study of the effects of fibers in water. The first major investigations of this possible problem are now being initiated. The impetus for these studies was supplied by the finding of asbestos-like material in the drinking water of Duluth, Minnesota.

The asbestos manufacturing industry grew rapidly in the first two-thirds of the 20th century. Many observers expect that growth will be less rapid in the future. Environmental and health considerations, plus competition from fiberglass, silicone products, aluminum sheet, and other materials, are among the factors contributing to the slowdown in growth. Many of the plants visited in this study were not operating at full capacity. New uses and markets for asbestos may be more difficult to develop in the future. Despite the decline in the rate of growth, asbestos has unique characteristics, and its use in manufacturing can be expected to continue to a significant degree in the foreseeable future.

SECTION IV

INDUSTRY CATEGORIZATION

INTRODUCTION AND CONCLUSIONS

In developing effluent limitations guidelines and standards of performance for new sources for a given industry, a judgment was made by EPA as to whether different effluent limitations and standards were appropriate for different segments (subcategories) within the industry. The factors considered in determining whether such categories were justified in the asbestos manufacturing industry were:

1. Product,
2. Raw Materials,
3. Manufacturing Process,
4. Treatability of Waste Waters,
5. Plant Size,
6. Plant Age, and
7. Geographic Location.

Based on review of the literature, plant visits and interviews, and consultation with industry representatives, the above factors were evaluated and it was concluded that the asbestos manufacturing industry should be divided into seven subcategories:

1. Asbestos-cement pipe,
2. Asbestos-cement sheet,
3. Asbestos-cement (starch binder),
4. Asbestos paper (elastomeric binder),
5. Asbestos millboard,
6. Asbestos roofing products, and
7. Asbestos roofing products.

FACTORS CONSIDERED

All of the factors listed above are briefly discussed below, even though most of them did not serve as bases for categorization.

Product

Despite some basic similarities in the manufacturing processes used to make the products in the first three categories above, the final products are distinct and are well defined and recognized within the industry. In most cases, only one asbestos product is made in a given plant. This basis for subcategorization is further supported by other factors mentioned below, but mainly by differences in raw waste loads and volumes.

Raw Materials

Many of the raw materials used in asbestos products are natural materials such as clay, portland cement, and starch. It is suspected that variations in these raw materials result in operational differences that influence the waste water volume and strength. There is no quantitative information in the industry about these influences. Moreover, changes within a product subcategory at a given plant may occur regularly and the amounts and types of raw materials may also be changed. These uncertainties did not permit subcategorization based on raw materials.

Manufacturing Process

Except for roofing and floor tile, the basic manufacturing processes are similar for the other asbestos products covered in this report. Within a given product subcategory, the basic manufacturing processes are very similar. Any differences that do exist do not greatly influence the quantity or quality of the effluent. However, differences in the number and size of auxiliary manufacturing units, such as save-alls, can greatly affect the waste water effluent, both in volume and strength. Therefore, the manufacturing processes could not be used as a basis for subcategorization.

Treatability of Waste water

While seemingly similar when described by the common collective parameters (suspended solids, oxygen demand, etc.), the waste waters from the different product categories exhibit some important differences. The differences relate both to the in-plant and end-of-pipe control measures and to the speed with which the category can be brought to the point where pollutants are not discharged. In general the raw waste load and volumes differed for each product subcategory. No great differences existed between the asbestos-cement pipe and asbestos-cement sheet subcategories, nor between the two asbestos paper subcategories. However, the evidence described in this report shows that asbestos-cement sheet plants will be able to achieve zero discharge sometime before asbestos-cement pipe plants. The same is true for asbestos paper (starch binder) versus asbestos paper (elastomeric binder).

Treatability of waste water is, therefore, the major factor supporting subcategorization based on products.

Plant Size

Plant size was not found to be a factor in categorizing the asbestos manufacturing industry. All of the plants visited had either one or two "machines." The machines are roughly of about the same capacity; and, consequently, all of the plants in a given category, or subcategory, do not range widely in size. The operational efficiency, quality of housekeeping, labor availability, and waste water characteristics of the plants do not differ because of size differences. The largest plants in the industry are actually multi-product plants and are, in reality, assemblages of individual product category manufacturing units.

Plant size does not affect the type or performance of effluent control measures. As described in Section VII, the basic waste treatment operation for this industry is sedimentation. Design is based on hydraulic flow rate and plants with smaller discharges can use smaller and somewhat less costly treatment units.

There are a few specialty plants with reported production levels that are very low. From the data provided, however, no significant differences in effluent characteristics of these plants could be detected. Not including these small plants, the approximate reported daily production ranges for the product categories are as follows:

Asbestos-cement pipe	135 to 329 kkg	(150 to 350 tons)
Asbestos-cement sheet	90 to 230 kkg	(100 to 250 tons)
Asbestos paper	45 to 90 kkg	(50 to 100 tons)
Asbestos millboard	6 to 14 kkg	(7 to 15 tons)
Asbestos roofing	(9360 to 450kkg)*	(400 to 500 tons)*
Asbestos floor tile	300,000 to 650,00 pieces	

*The limited data from roofing plants do not permit an accurate estimate of the full range of production.

Plant Age

The ages of the plants in the asbestos manufacturing industry range from a few to 50 or more years. The manufacturing equipment is often younger than the building housing the plant, although in some cases used machines have been installed in new plants. Plant age could not be correlated with operational efficiency, quality of housekeeping, or waste water characteristics. Plant age is not an appropriate basis for categorization of the industry.

Geographic Location

Asbestos manufacturing plants are primarily in the east and south and in California. There are reportedly no differences in the processes used throughout the country. Plants in some southwestern locations are able to reduce the volume of discharge because of high evaporation losses from lagoons. There are insufficient data upon which to base standards for these plants. This form of treatment is not available throughout most of the nation.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

INTRODUCTION

Water is commonly used in asbestos manufacturing as an ingredient, a carrying medium, for cooling, and for various auxiliary purposes such as in pump seals, wet saws, pressure testing of pipe, and others. These uses are described in detail in following parts of this section. Water is used only for cooling in the manufacture of asbestos roofing and floor tile products. In the discussion below, these two categories are not included unless specifically mentioned. In most asbestos manufacturing plants the waste waters from all sources are combined and discharged in a single sewer.

As described in detail in Section IV, asbestos manufacturing, in almost all cases, involves forming the product from a dilute water slurry of the mixed raw ingredients. The product is brought to the desired size, thickness, or shape by accumulating the solid materials and removing most of the carriage water. The water is removed at several places in the machine and it, together with any excess slurry, is piped to the save-all system.

The mixing operations are carried out on a batch, or semi-continuous basis. Water and materials are returned from the save-alls as needed during mixing. Excess water and, in some cases, materials are discharged from the save-all system. Fresh water and additional raw materials are added during mixing. The fresh water is often used first as vacuum pump seal water before going into the mixing operations.

The major source of process waste water in asbestos manufacturing is the "machine" that converts the slurry into the formed wet product. It is not practical to isolate individual sources of waste water within the machine system. The water is commonly transported from the machine to the save-all system and back to the machine in a closed system. To measure the quantity of water flowing in the machine-save-all recycle system involves a rather elaborate monitoring program that was beyond the scope of this study. Only one manufacturing plant provided data on in-plant water flows that were more than rough estimates. This information is presented below under asbestos-cement pipe (Figure 9). The relative amount of internal recycling in all asbestos manufacturing plants is significant and of roughly the same relative proportion as detailed for this pipe plant.

An important factor influencing both the volume and strength of the raw waste waters is the save-all capacity in the plant. Save-alls are basically settling tanks in which solid-liquid separation is accomplished by gravity. Their purpose is first to

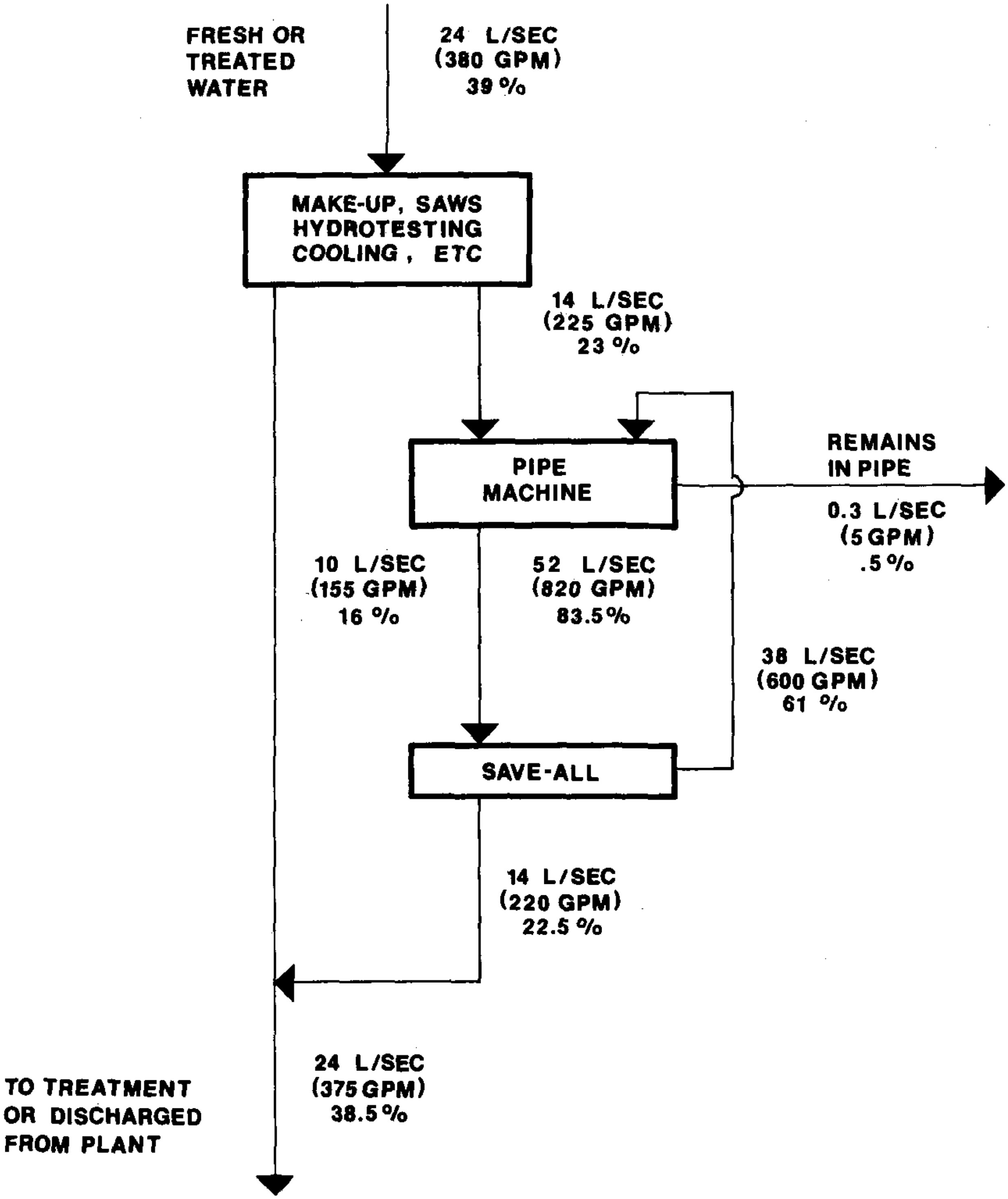


Figure 9.- Water Balance Diagram for a Typical Asbestos-Cement Pipe Plant

recover raw materials (solids) and, second, water. The efficiency of separation is primarily dependent upon the hydraulic loading on the save all. Plants with greater save-capacity have greater flexibility in operation, more water storage volume, and a cleaner raw waste water leaving the manufacturing process. In many asbestos manufacturing plants, the solids in the save-alls are dumped when the product is to be changed or when it is necessary to remove the accumulated waste solids at the bottom. It may also be necessary to dump the save-alls when the manufacturing process is shut down.

ASBESTOS-CEMENT PIPE

Water Usage

The water balance at one asbestos-cement pipe plant was provided by the plant personnel. The values were verified in this study as far as possible. The balance is outlined diagrammatically in Figure 9. The fresh water going into the pipe manufacturing machine is only about one-quarter of the total used. The rest is water recycled from the save-all. The percentage figures in Figure 9 are in terms of the total water entering the manufacturing system, i.e., the fresh water and that returned from the save-all.

Fresh water is used for wet saws, hydrotesting, cooling, sealing vacuum pumps, and making steam for the autoclave as well as make-up in the mixing unit. Water is used with the saws to control dust and fiber emissions to the air. This is in contrast to the normally dry lath operations that finish the pipe ends.

Hydrotesting is a routine procedure in which the strength of the pipe is tested while full of water under pressure. At some plants, the hydrotest water is reused.

A pipe plant must remove solids from the bottom of the save-alls to prevent their hardening into concretions. At some plants, this dumping and clean up is carried out when the manufacturing operations are shut down for the weekend. At other plants, dumping occurs more frequently.

The reported waste water discharge from 10 of the 14 asbestos-cement pipe plants ranges from 76 to 2,080 cubic meters per day (0.02 to .55 MGD). The plants with minimal effluent volumes discharge about 5.0 to 6.3 cu m per metric ton (1200 to 1500 gal per ton) of product. The accuracy of these values is not known. At a few locations, there is reduced discharge because of evaporative losses from lagoons. Discharge records for a period of a year or more were available at two pipe plants. At one plant the minimum flow was 65 percent of the average and the maximum was 145 percent. The flow figures included cooling water from the manufacture of plastic pipe, however. The maximum discharge at the other plant, which produced only asbestos-cement pipe, was 670 percent of the average. The standard deviation in 403 values at this plant was of the same magnitude as the average flow.

Waste Characteristics

The characteristics of raw waste waters from asbestos-cement pipe manufacturing were developed from sampling data from three plants and reported values from one plant that provides minimal treatment. Two of the plants recirculated water from the external treatment system back into the plant. These plants tended to use relatively much more water and the dissolved (filterable) solids levels were much higher in the waste waters from these plants.

Constituents-

The manufacture of asbestos-cement pipe in a typical plant increases the levels of the major constituents in the water by the following approximate amounts:

	mg/l	kg/kkg	(lb/ton)
Total solids	1,500	9	18
Suspended solids	500	3.1	6.3
BOD5 (5-day)	2	0.01	0.02
Alkalinity	700	4.4	8.8

The dissolved salts are reported to be primarily calcium and potassium sulfates with lesser amounts of sodium chloride. The magnesium levels are not known to be high. The alkalinity is primarily caused by hydroxide with a small carbonate contribution. The pH ranges as high as 12.9, but is generally close to 12.0, or slightly lower.

Temperature--The temperature fluctuations at a given plant are smaller than the differences between plants. The maximum raw waste temperature measured in this study was 40 degrees C. This plant recirculated some water from its treatment facility. The average temperature at two other pipe plants were 10 to 15 degrees C hotter than the intake water.

Oil and grease--The oil and grease content of raw waste samples taken at pipe plants was below detectable levels. Reported data indicate that at some plants there are measurable oil and grease levels in the final plant effluent. This is believed to be from the equipment rather than the process.

Organic matter--The organic content of pipe plant waste waters is normally low. Some plants use organic acids (acetic) to clean the mandrels and to remove scale in the plant. This could contribute BOD5 to the waste stream. The waste acid is neutralized when mixed with the highly alkaline process waste stream. The high pH precludes the presence of any biological forms.

Plant nutrients--The measured and reported average levels of the plant nutrients nitrogen and phosphorus in pipe plant effluents were below 2.5 mg/l and 0.05 mg/l, respectively. There are unconfirmed peak values at individual plants of Kjeldahl nitrogen values as high as 12 mg/l and total phosphorus levels of 0.4 mg/l.

Other chemicals--The information on other constituents was derived from reported data from a few individual plants. Most plants did not have data on every constituent. Among the constituents reportedly measured in the effluents from some asbestos-cement pipe plants are chromium, cyanide, mercury, phenols, and zinc. Based on the limited data available, the levels were not judged to be significant.

Color and turbidity--The raw waste waters from pipe manufacture are very turbid and of a gray-white color. When the solids are removed, the water has no color.

Fluctuations--The variations in raw waste loadings from a typical plant are not known. No plant measures or records the characteristics of the raw waste waters. The waste water treatment systems are designed on hydraulic principles and their operational efficiency is largely independent of the strength of the influent waste water.

The changes in waste characteristics associated with start-up of a pipe plant are minor and less than the normal fluctuations associated with operation. When a pipe plant is shut down and the save-alls dumped, there is released a heavy charge of suspended solids in a short period of time. Other parameters remain the same or decrease slightly because of dilution by the flush water. Grab samples of raw pipe waste waters collected during clean-up at one plant gave results in the following ranges:

Total solids	1,400	to 3,100 mg/l
Suspended solids	300	to 2,900 mg/l
Alkalinity	540	to 2,000 mg/l

Fluctuations in raw waste water quality should not cause serious problems in the physical treatment facilities appropriate for pipe plant wastes.

ASBESTOS-CEMENT SHEET

Water Usage

No information is known to be available about the internal water balance in an asbestos-cement sheet plant. It is expected that the percent recycle from the save-alls is roughly the same as for asbestos-cement pipe (Figure 9).

The reported waste water discharge from 4 of the 13 known sheet plants ranges from 280 to 2,040 cubic meters per day (0.07 to .54 MGD). The raw waste flows from the three sheet plants sampled during this study were 570, 650, and 920 cu m/day (0.15, .17, and .24 MGD). The largest of the three values was from a plant that discharges no effluent and, consequently, may use relatively more water. The minimal effluent volume from a plant was 7.5 cu m per metric ton (1800 gal per ton) of production.

There are no known monitoring records of discharge from asbestos - cement sheet plants and no estimate of the minimum, maximum, and variability of the flow from a plant can be made.

Waste Characteristics

The characteristics of raw waste waters from asbestos-cement sheet manufacturing were developed from sampling data from two plants. No other data were available except that reported by one plant using the wet press forming technique to make high-density sheet. Since this product may include pigments and other additives and since it is produced at only two known locations, neither of which have adequate data, it is not properly included in this category.

Constituents--

The manufacture of asbestos-cement sheet products in a typical plant increases the level of constituents in the water by the following approximate amounts:

	mg/l	kg/kkg	(lb/ton)
Total solids	2,000	15	30
Suspended solids	850	6.5	13
BOD_5 (5-day)	2	0.015	0.03
Alkalinity	1,000	7.5	15

Little information is available on the dissolved salts in sheet wastewaters, but they should be similar to those from asbestos-cement pipe manufacture. The alkalinity is caused primarily by hydroxide with a pH averaging 11.7 and ranging from 11.4 to 12.4 in all reporting plants.

Temperature--Meaningful temperature data was available from only one sheet plant. With a flow of 920 cu m/day (0.24 MGD), the temperature was increased 13 degrees C in the sheet manufacturing process. The reported peak summer temperatures of waste waters discharged from asbestos-cement sheet plants was 50 degrees C.

Oil and grease--The presence of oil and grease in waste waters from sheet plants has not been reported. No measurable oil and grease was found in the samples analyzed in this study.

Other constituents--The discussion regarding organic content, plant nutrients, other chemicals, turbidity and color, and fluctuations of the characteristics of asbestos-cement pipe waste waters applies to those from asbestos-cement sheet.

ASBESTOS PAPER

Water Usage

The reported total waste water discharges from 5 of the 12 asbestos paper manufacturing plants range from 490 to 4,900 cubic meters per day (0.13 to 1.3 MGD). The accuracy of these values is not known. The volumes of raw waste water discharged to the treatment facility at two plants visited in connection with this study were 1,700 and 2,700 cu m/day (0.45 and 0.72 MGD). Many plants recirculate water and solids from the waste water treatment facility to the paper making process and the effluent volume is considerably less than the raw waste water discharge.

An effluent flow of 13.8 cu m per metric ton (3,300 gal. per ton) was reported at the exemplary plants.

Information about variability of flow is available from one plant only. This is the monitoring record of the treated effluent over a recent eight-month period. The average flow was 490 cu m/day (0.13 MGD) with minimum and maximum values of 430 and 755 cu m/day (0.14 and .20 MGD), respectively. The standard deviation of the 113 readings taken during the period was 53 cu m/day (0.014 MGD). The exact quantities of water recycled from the save-all system and from the waste treatment facility at this plant are not known.

Waste Characteristics

The raw waste water characteristics from asbestos paper manufacturing were developed from sampling data at two plants. Both plants provide high levels of waste water treatment with low volumes of effluent discharge. Consequently, the use of water within these two plants may be higher than in plants that do not recycle treated waste water.

Constituent--

The manufacture of asbestos paper in a typical plant increases the levels of the constituents in the water by the following approximate amounts:

	mg/l	kg/kkg	(lb/ton)
Total solids	1,900	26	52
Suspended Solids	680	9.5	19
BOD5 (5-day)	110	1.5	3
COD	160	2.2	4.4

The pH of raw waste waters from asbestos paper manufacturing is 8.0 or lower.

Temperature--The highest reported summer temperature value for treated effluent is 32 degrees C. It is believed that heated water is used in mixing the raw materials at most plants, although at least one uses cold water. Recycled water tends to have a higher temperature.

Oil and grease--Oil and grease was detected in only one of the samples collected at the two paper manufacturing plants. The level was low, 1.2 mg/l, and was believed to be from plant equipment. This type of material is not part of the product ingredients.

Organic matter--The oxygen demand is believed to be largely due to the organic binders, i.e., starch or synthetic elastomers. These latter include several materials of different chemical compositions.

Nutrients--The total nitrogen levels reported in effluents from a few paper plants averaged 16 mg/l, with the Kjeldahl fraction about 11 mg/l. Phosphorus levels ranged from 0.25 to 1.0 mg/l.

Other chemicals--Trace amounts of copper, mercury, and zinc were reported to be in the wastes from individual asbestos paper plants. The levels were judged not to be significant.

Color--The clarified waste waters are known to have some color. The levels at two plants were 10 and 15 units.

Fluctuations--There was greater variability among the data from the two paper plants than observed in most other asbestos manufacturing operations. There are no data on the variations in quality of raw asbestos paper waste waters other than the sampling results and these were from too limited a period of time to be of value. Results from the monitoring program at one paper plant were cited above under Water Usage. Although they refer to treated effluent, they provide some indication of the variability of the waste water characteristics, as follows:

	Minimum	Average	Maximum	Std Dev'n
Total Solids	500 mg/l	685 mg/l	870 mg/l	260 mg/l
Suspended Solids	32	64	95	44
BOD5 (5-day)	22	57	91	48

Unlike asbestos-cement products plants, asbestos paper plants do not use portland cement and the solids in the save-alls do not tend to form concretions. Shut-down is less regular and the plants tend to operate around the clock. Shut-downs are sometimes necessary when changing products. Since the elastomeric binders are not always compatible, the save-all solids may be dumped at these times. There were no routine shut-down or start-up operations while the paper plants were being sampled in this study and there is no information on the characteristics of the raw waste waters during these periods.

ASBESTOS MILLBOARD

There are seven known locations where asbestos millboard is manufactured. At all of these locations, the waste waters are either discharged to municipal sewers or are combined with other asbestos manufacturing waste waters. Consequently, there is almost no information from the industry about the quantity and quality of millboard waste waters. The results presented below are based primarily upon the sampling program carried out for this study at two plants.

Water Usage

The water leaving the save-all systems at the two plants amounted to 41 and 136 cubic meters per metric ton (12,000 and 39,500 gallons per ton). One plant discharges its waste waters to a large lagoon system and recycles all of the lagoon effluent into the plant. This is a multi-product plant. The other plant normally recycles all of its save-all effluent. Surges due to upsets or shut-down are released to a municipal sewer. Since neither plant has any measurable effluent on a regular basis, the amounts of water used in the manufacturing process may not be representative of the amounts discharged by a plant that does not recycle its waste water.

Waste Characteristics

Constituents-

At the plant that discharges its waste waters to the lagoon system, the constituents added to the water were measured as follows:

	mg/l	kg/kkg	(lb/ton)
Suspended Solids	35	1.8	3.5
BOD5 (5-day)	5	0.25	0.5

The total solids and COD levels in the water leaving the millboard save-alls were the same as those of the make-up water. The pH of the raw waste water ranged from 8.3 to 9.2. Some millboard is manufactured with portland cement and the pH would be higher in such cases.

The effluent from the save-all system at the millboard plant that operates with a completely closed water system had the characteristics listed below. In such a plant, the waste constituents accumulate until a steady-state level is reached. The contribution of each manufacturing cycle cannot be determined directly and, consequently, raw waste loadings expressed in terms of production units are meaningless.

	Average	Range
Total solids	6,100 mg/l	3,950 to 7,800 mg/l
Suspended solids	5,100	3,060 to 6,270
BOD_5 (5-day)	2	-
COD	62	10 to 145

The pH ranged from 11.8 to 12.1 and the alkalinity from 2,000 to 2,700 mg/l, mostly in the hydroxide form.

Temperature--The temperatures of the raw waste waters at the two sampled millboard plants were 12 and 26 degrees C, with the higher temperature measured at the completely closed system. The highest reported summer temperature of the effluents at two other millboard plants was 31 degrees C.

Other constituents--Small amounts of oil and grease, nitrogen, and phosphorus were detected in some of the samples collected in this study.

No information is available from the millboard industry on the presence of plant nutrients, toxic constituent, or about the nature of the additive materials that are used in the many varieties of millboard.

Fluctuations--No information is available by which to accurately estimate the degree of fluctuation in millboard waste water characteristics. Judging from the differences in the two plants that were sampled and from the relatively broad range of raw materials used, the variability of waste waters from millboard manufacture is high.

ASBESTOS ROOFING

Unlike the asbestos products covered previously, water is not an integral part of roofing products. It is used, however, to cool the roofing after saturation. All plants use non-contact cooling and some use spray contact cooling. The roofing is largely, but not completely, inert to water and the contact cooling water becomes a process waste water. This contaminated cooling water is discharged with the non-contact cooling water in some plants, resulting in a large volume of dilute process waste water.

Water Usage

The discharge volumes vary widely among the few roofing plants that reported information on flows, ranging from 145 to 2,100 liters per metric ton (35 to over 500 gallons per ton) of product. The original temperature of the cooling water, whether it is once-through or recirculated, and whether non-contact water is included are factors influencing the reported amount of water discharged. The fluctuations in flow rate should be minimal at a given location.

Waste Characteristics

The characteristics of spent cooling water from roofing manufacture are developed from sampling data taken at one plant. This plant employs surface sprays and discharges the contact and non-contact cooling water into a common sewer. The combined waste water was sampled. At the time of sampling, the roofing was being made from organic (non-asbestos) paper. Since the water spray contacts only the outer bituminous surface and not the base paper, it is believed that the samples are representative of wastes from contact cooling of asbestos-based roofing.

The added quantities of the major constituents were as follows:

	mg/l	kg/kkg	(lb/ton)
Suspended solids	150	0.06	0.13
BOD_5 (5-day)	6	0.003	0.005
COD	20	0.008	0.016

The pH of the waste water averaged 8.2.

Temperature--The temperature of the spent cooling water was 13 degrees C, a 7-degree increase over the temperature of the intake water at a flow rate of about 1,420 cubic meters per day (0.375 MGD).

Supplemental data--Information about the effluents from one other asbestos roofing plant was reported by the manufacturer. The waste water is treated by settling, oil skimming, and passage through an adsorbant filter. The added quantities of materials are reported to be:

	mg/l	kg/kkg	(lb/ton)
Suspended solids	37	0.06	0.12
BOD_5 (5-day)	37	0.07	0.13
COD	91	0.15	0.30

The average pH of the effluent is reported to be 6.8.

Other constituents of interest were measured in this treated effluent with the following average results in terms of added quantities:

	mg/l	g/kkg
Total Solids	93	0.16
Total Organic Carbon	1	0.00015
Cyanide	0.00003	0.00005
Copper	0.019	0.03
Iron	0.031	0.05
Lead	0.001	0.0015
Nickel	0.003	0.005
Zinc	0.071	0.12
Oil and Grease	1.6	0.0025
Phenols	0.003	0.005

Total nitrogen and phosphorus levels in the cooling water were each increased about 0.5 mg/l by passage through the plant. Arsenic, cadmium, and chromium were analyzed for, but not detected in, the effluent.

The above information on treated roofing waste waters is presented as supplemental data. It has not been verified, but it does provide an insight into the strength and character of the waste waters from asbestos roofing manufacture.

Fluctuations--There is insufficient information to describe variations in the characteristics within a plant or among plants in this category. Since the waste water is spent cooling water, its characteristics should be unaffected by start-up and shut-down operations.

ASBESTOS FLOOR TILE

From a water use and waste water characterization point of view, vinyl and asphalt tile manufacturing both produce the same result. Like roofing, water is used only for cooling purposes. Both contact and non-contact cooling are usually employed. Water does not come into contact with the tile until it has been heated and rolled into its final form. In this stage it is completely inert to water.

Water Usage

Cooling water usage information was available from six floor tile plants with an average daily production of about 400,000 pieces. The reported discharges ranged from about 80 to 1,700 liters (21 to 450 gallons) per 1,000 pieces with an average of 1,130 liters (300 gallons).

The wide range reflects differences in intake water temperatures, whether or not the water is recirculated, and whether both contact and non-contact waters are included in the figures. Because the water is used for cooling, fluctuations within a given plant should not be large and should primarily be the result of changes in production levels or seasonal temperature changes, or both.

Waste Characteristics

Despite the facte that floor tile itself is inert in water, the contact cooling water becomes contaminated with a diverse variety of materials including wax, inks, oil, glue, and miscellaneous dirt and debris. The material has a high organic content although the limited data available indicate that it is not readily biodegradable.

Constituents-

The added waste constituents in a typical floor tile plant are as follows:

	mg/l	kg/1000 pc*	(lb/1000 pc*)
Suspended Solids	150	0.18	0.40
BOD_5 (5-day)	15	0.02	0.04
COD	300	0.36	0.80

* pc- pieces of tile, 12"x12"x3/32"

The reported pH of tile plant waste waters ranges from 6.9 to 8.3, averaging 7.3.

Temperature--The reported temperature data are inconsistent among the few plants reporting. Some plants with large per unit flow volumes show a larger temperature increase than plants with much smaller flows per 1,000 pieces.

Oil and grease--Oil and grease are reportedly present in tile plant effluents, with an average concentrations of 5.5 mg/l after treatment.

Organic matter--The COD is believed to be largely associated with the suspended solids with much of it being wax.

Plant nutrients--The limited data on plant nutrients indicate that the increased total nitrogen and phosphorus levels should be less than 5.0 and 1.5 mg/l, respectively.

Other chemicals--Trace amounts of phenols and chromimum were each reported by one plant. The levels were judged not to be significant.

Color and turbidity--Data on the color and turbidity of waste waters from floor tile manufacture are not available. The wastes do have measurable levels of both parameters, however.

Fluctuations--There are no known data by which to assess the variations in constituent concentrations in waste waters from floor tile plants.

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

SELECTED PARAMETERS

The chemical, physical, and biological parameters that define the pollutant constituents in waste waters from the asbestos manufacturing industry are the following:

- Total suspended solids
- BOD_5
- COD (or TOC)
- pH
- Temperature
- Dissolved solids
- Nitrogen
- Phosphorus
- Phenols
- Heavy metals

The last four listed parameters are not normally present in high concentrations. Individual plants have reported significant levels of one or more in their effluents, however, and they are therefore included.

Asbestos itself is not included in the list for several reasons. The suspended solids present in the waste waters are to a large extent asbestos fibers. Removal of suspended solids by sedimentation will also remove asbestos fibers but there exists no data at the present time on which to determine a definitive relationship.

The agency is particularly concerned over the potential effects of the discharge of asbestos fibers. It is therefore suggested that the industry assess the extent of asbestos fiber discharges in the effluent stream, after treatment and control, and take appropriate additional measures to reduce such discharge.

Pollutants in non-process waste waters, such as discharges from noncontact cooling systems, boiler blowdown, and wastes from water treatment facilities are not included in this document.

The rationale for selection of the listed parameters is given below. In the following paragraphs, the terms used to describe the levels of the various parameters are relative within this industrial category. For example, a BOD_5 level of 100 mg/l is high for asbestos manufacturing waste waters, but is low compared to many industrial wastes.

The reasons for including the above listed parameters are briefly presented below. The reader is referred to other sources (Section XIII) for further descriptions of the parameters and procedures for measuring them.

Total Suspended Solids

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems, and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low.

The suspended solids levels in raw asbestos manufacturing waste waters are often high with levels commonly in the 500 to 1,000 mg/l range. The solids are heavy and settle quickly. They would produce sludge deposits on the bottom of receiving water bodies if discharged. The solids could also contribute turbidity and possibly harm aquatic life if suspended in receiving waters. The asbestos fiber content of the solids is reported to be relatively low, with the bulk of the solids originating as cement, silica, clay, and other raw materials.

Chemical Oxygen Demand (COD)

Moderately high COD values are typically associated with raw waste waters from asbestos paper, roofing, and floor tile manufacturing. The binders used in paper are believed to be the major source of COD. The elastomeric binders result in high COD results, but contribute little BOD_5. In other words, they are *not readily biodegradable. The COD in roofing waste waters is* caused by soluble bitumens, phenols, oil and grease from bearings, and other materials that contaminate the contact cooling water. It is believed that wax contributes the major portion of COD in raw waste waters from floor tile production.

pH, Acidity and Alkalinity

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour." The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Raw waste waters from products that contain portland cement normally have an elevated pH value. The pH of asbestos-cement wastes is close to 12 or higher. This indicates a caustic (hydroxide) alkalinity that should be neutralized before discharge to receiving waters or municipal sewers. Highly caustic waters are harmful to aquatic life.

OTHER POLLUTANTS

The following parameters were considered in the course of this study. They were not included in the effluent guidelines and standards for one or more of the following reasons: the amounts found in the waste waters were insignificant, or insufficient data was available upon which to base a limitation. In particular, treatment to reduce dissolved solids levels is judged to be beyond the scope of "best practicable" treatment based on cost availability of the technology. Since the "best available" treatment recommended is no discharge of process waste waters, this constituent will be completely removed by 1983. Rationale for establishing temperature limitations are presently not available.

Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced D.O. concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

The BOD_5 levels in wastes from asbestos-cement, roofing, and floor tile product manufacture are usually very low. Important BOD_5 contributions originate with the natural organic binders used in some asbestos papers and millboards. The typical maximum levels are about 100 mg/l.

Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthinc organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the esthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

Thermal increases are caused by chemical reactions, heating, and contact cooling in various parts of the asbestos products industry. Reported temperatures for effluents reach maximum levels of 38 degrees C (100 degrees F). Recirculated water is relatively hotter than that which is used once and discharged.

Dissolved Solids

In natural waters the dissolved solids consist mainly of carbonates, chlorides, sulfates, phosphates, and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese and other substances.

Many communities in the United States and in other countries use water supplies containing 2000 to 4000 mg/l of dissolved salts, when no better water is available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4000 mg/l of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated whereas they could not be in temperate climates. Waters containing 5000 mg/l or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for fresh-water fish may range from 5,000 to 10,000 mg/l, according to species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of fresh-water forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/l. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities such as those resulting from discharges of oil-well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids over 500 mg/l have decreasing utility as irrigation water. At 5,000 mg/l water has little or no value for irrigation.

Dissolved solids in industrial waters can cause foaming in boilers and cause interference with cleaness, color, or taste of many finished products. High contents of dissolved solids also tend to accelerate corrosion.

Specific conductance is a measure of the capacity of water to convey an electric current. This property is related to the total concentration of ionized substances in water and water temperature. This property is frequently used as a substitute method of quickly estimating the dissolved solids concentration.

In addition to the high suspended solids levels in most raw waste waters from asbestos manufacture, the dissolved (filterable) solids are often of equal or greater magnitude. These originate primarily with the major raw materials, i.e., cement, clays, etc. Sulfates are reported to be one of the major dissolved components in the case of asbestos-cement products. The levels in some plant effluents are high enough to be of concern in public water supplies if not adequately diluted by the receiving water.

Nitrogen and Phosphorus

During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element in all of the elements required by fresh water plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows use of other, already present, nutrients for plant growths. Phosphorus is usually described, for this reasons, as a "limiting factor."

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as an physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l.

Nitrogen levels in raw waste waters from asbestos manufacturing are normally not high, with reported maxima for total nitrogen of about 15 mg/l. It is included here because nitrogen at this level could influence eutrophication rates in some water bodies.

In some cases, the sources of nitrogen are the minor ingredients and additives in the product, rather than the principal raw materials. These secondary ingredients are subject to change and the nitrogen levels in the waste water should be monitored to insure that excessive levels are absent.

Maximum phosphorus levels in asbestos waste waters are typically in the 1 to 2 mg/l range. Like nitrogen, this element can influence eutrophication and should be monitored to insure that levels are acceptably low.

Phenols

Phenols and phenolic wastes are derived from petroleum, coke, and chemical industries; wood distillation; and domestic and animal wastes. Many phenolic compounds are more toxic than pure phenol; their toxicity varies with the combinations and general nature of total wastes. The effect of combinations of different phenolic compounds is cumulative.

Phenols and phenolic compounds are both acutely and chronically toxic to fish and other aquatic animals. Also, chlorophenols produce an unpleasant taste in fish flesh that destroys their recreational and commercial value.

It is necessary to limit phenolic compounds in raw water used for drinking water supplies, as conventional treatment methods used by water supply facilities do not remove phenols. The ingestion of concentrated solutions of phenols will result in severe pain, renal irritation, shock and possibly death.

Phenols also reduce the utility of water for certain industrial uses, notably food and beverage processing, where it creates unpleasant tastes and odors in the product.

The presence of measurable phenol levels have been reported in wastes from roofing manufacture. These chemicals cause serious taste and odors in water supplies and their entry to the waste stream and should be maintained to insure that levels are acceptably low.

Heavy Metals

Individual plants have reported that one or more of the following metals were present in trace quantities in their effluents; barium, cadmium, chromium, copper, mercury, nickel, and zinc. Two pipe plants reported that cyanides were present in their wastes. These materials were at levels well below those specified as safe for drinking water. There was no consistent pattern detected among the limited data available. These materials may originate in the major raw materials or in the minor ingredients and additives. Excessive effluent levels could probably be most economically controlled by changing or elimination of the source.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

INTRODUCTION

Those parts of the asbestos manufacturing industry covered in this document fall into two groups: (1) asbestos-cement products and asbestos paper and millboard, and (2) roofing and floor tile. The waste waters from the second group are contaminated contact cooling waters and are relatively smaller in volume. The level and type of control and treatment measures for roofing and floor tile plants are different than those for the product categories in the first group. Most of the general material below applies to the plants in the first group.

Waste Characteristics

The process waste waters from the manufacture of asbestos-cement pipe, asbestos-cement sheet paper, and millboard represent the major sources of pollutant constituents in the asbestos manufacturing industry. The wastes originate from several points in the manufacturing processes and they are usually combined into a single discharge from the plant. The wastes from all of these categories are similar in many characteristics and they are amenable to treatment by the same operation, namely, sedimentation. Because of similarities in manufacturing processes, many in-plant control measures apply at all locations.

Treatment

Sedimentation, with various auxiliary operations, yields an effluent of low pollution potential when properly applied to asbestos manufacturing waste waters. The settled solids are inert, dense, and appropriate for landfill disposal as described in Section VIII. While present practices within the industry are not achieving the best possible results in all cases, they can be upgraded without major technical problems.

Treatment beyond sedimentation and pH control is not appropriate for wastes from the major product categories in the asbestos manufacturing industry. The only pollutant constituent remaining at significant levels, other than temperature, is dissolved solids. While these levels may be at undesirably high levels for certain industrial water uses, they do not present serious hazards to human health or to aquatic life. To remove the dissolved solids burden in these waste waters would require advanced treatment operations techniques, e.g., reverse osmosis, electrodialysis, or distillation. The initial and annual costs associated with these advanced treatment operations are so high that alternative solutions, namely, complete recycle of waste waters, will be implemented by the industry instead of further treatment.

During the course of the study carried out to prepare this document, representatives of at least six of the companies listed in Section III volunteered the information that complete recirculation of process waste waters was presently under consideration, being developed, or actively being implemented.

Implementation

The in-plant control measures and end-of-pipe treatment technology outlined below can be implemented as necessary throughout the asbestos manufacturing industry. Factors relating to plant and equipment age, manufacturing process and capacity, and land availability do not play a significant role in determining whether or not a given plant can make the changes. Implementation of a particular control or treatment measure will involve approximately the same degree of engineering and process design skill and will have the same effects on plant operations, product quality, and process flexibility at all locations.

IN-PLANT CONTROL MEASURES

Many asbestos manufacturing plants incorporate some in-plant practices that reduce the release of pollutant constituents. These practices have resulted in economic benefits, e.g., reduced water supply or waste disposal costs, or both. Few plants include all of the control measures that are possible, however.

Raw Material Storage

Raw materials are normally stored indoors and kept dry. There are no widespread water pollution problems related to improper raw materials storage practices.

Waste Water Segregation

In all cases, sanitary sewage should be disposed of separately from process waste waters. Public health considerations as well as economic factors dictate that sanitary wastes not be combined with asbestos process wastes.

Other non-process waste waters are often combined with manufacturing wastes in asbestos plants. A careful evaluation should be made in each plant to determine if some or all of these wastes could be segregated and recirculated. Such reduction in waste volumes might result in smaller, more economical waste treatment facilities.

Housekeeping Practices

Except for roofing and floor tile plants, housekeeping practices do not greatly influence the waste water characteristics. The use of wet clean-up techniques are common to control fiber and dust air emissions. In view of the alternative, continuation of the proper use of such wet methods should not impair the efficiency of end-of-pipe treatment facilities.

Water Usage

Fresh water should be used first for pump seals, steam generation, showers, and similar uses that cannot tolerate high contaminant levels. The discharges from these uses should then go into the manufacturing process as make-up water and elsewhere where water quality is less critical.

Water conservation equipment and practices should be installed to prevent overflows, spills, and leaks. Plumbing arrangements that discourage the unnecessary use of fresh water should be incorporated.

Plans should be made for complete recirculation of all waste waters. This will permit the installation of new equipment and the making of the plant alterations as part of an integrated, long-range program. In some cases, it may be more economical for a given plant to move directly toward complete recirculation rather than install extensive treatment facilities.

In line with water use practices, evaluation of the benefits of increased save-all capacity should be made at some plants. This would provide more in-plant water storage, permit greater operating flexibility, and reduce the level of pollutant constituents in the raw waste waters discharged from the plant.

Product Categories

In-plant control measures applicable to specific asbestos product manufacturing operations are given below.

Asbestos-Cement Pipe-

Some pipe plants completely recirculate the water used in the hydrotest operation. Some plants reuse part of the autoclave condensate directly. Consideration should be given to piping waste waters from wet saws to the save-all system.

At least one pipe plant recycles a major fraction of the effluent from its waste treatment facility back into the manufacturing process.

No plant making only asbestos-cement pipe has accomplished complete recirculation. A reported experimental attempt to do so by one company was not successful.

The raw waste water flow from asbestos-cement pipe manufacture is typically in the range of 4.1 to 5.2 cubic meters per metric ton (1200 to 1500 gallons per ton) of product.

Asbestos-Cement Sheet Products-

Many of the in-plant control measures described above for pipe plants could be incorporated in sheet plants. The raw waste water flow from sheet manufacture is typically in the range of 5.2 to 6.2 cu m/kkg (1500 to 1800 gal/ton).

One asbestos-cement sheet plant achieves complete recirculation most of the time. The manufacturing process is so balanced that the fresh water intake equals the amount of water in the wet product. Fresh water enters the system only for boiler make-up and as part of the vacuum pump seal water. This plant is connected to a municipal sewer and excess flows caused by upsets and process shut-downs are discharged intermittently. With sufficient holding capacity to accommodate these surges, discharge to the sewer could be eliminated.

The benefits of complete recycle at this plant include reduced water cost and sewer service charges, minimal asbestos loss and, reportedly, a somewhat stronger product.

The major problem encountered in complete water recycle at this plant is scaling. Spray nozzles require occasional unplugging, the water lines are scoured regularly with a pneumatically driven cleaner, and fine sand is introduced into the pumps to eliminate deposits.

While one sheet plant has accomplished almost complete recirculation, this is not regarded as fully demonstrated technology. This plant makes only a few asbestos-cement sheet products. The intermittent discharge to the sewer does provide some blowdown relief to the system. Whether such complete recirculation could be applied to plants making sheet products with more stringent quality specifications is not known. The progress at this plant does indicate that complete recirculation is a realistic goal for the future.

Asbestos Paper-

The in-plant control measures outlined above for asbestos-cement pipe can be applied in part in asbestos paper making plants. One paper plant has been able to close up its process water system when making paper with a starch binder. Such operation is not possible when elastomeric binders are used and excess water is then discharged to the municipal sewer.

An asbestos paper plant that practices partial recycle of water from its waste treatment unit typically discharges within 30 percent of 11 cu m/kkg (3,300 gal/ton).

Partial recycle of water and underflow solids from the waste water treatment facility is not uncommon in the asbestos paper industry. Complete recirculation and zero discharge has not been demonstrated on a continuing basis at any plant making only paper. It is likely that paper could be manufactured using a closed system if only starch binders were used. Total and continuous recycle of water and solids when using elastomeric binders cannot be accomplished today. Since some paper plants use both types of binders, a guideline based on the type of binder used would be impractical.

That significant recycle of waste water has been accomplished indicates that complete recirculation is a possible goal for the future.

Asbestos Millboard-

One plant that produces a wide variety of millboard products with a relatively small save-all system presently achieves almost complete recycle of the process water. The stimulus at this location was, at least in part, high costs for water and sewer services. The plant releases save-all overflow to the municipal sewer when upsets or product changes occur. With greater save-all capacity or a holding tank, this plant could accomplish zero discharge on a continuous basis.

In connection with this study, four of the seven known millboard plants in the country were visited. Since almost complete recirculation has been demonstrated in a typical plant, it is believed that zero discharge can be achieved soon by millboard manufacturing plants.

Asbestos Roofing-

The plants that practice contact cooling should evaluate the possibility of eliminating this source of process waste water. If this were done, and leaks and other losses of non-contact cooling were closed and dry cleaning practices instituted, the asbestos roofing industry would be able to operate without the discharge of process waste waters.

In any case, non-contact cooling water and condensate should not be mixed with contact cooling water. This practice greatly increases the volume of process waste water to be treated.

Asbestos Floor Tile-

There are several in-plant measures that should be used in floor tile plants to control the release of pollutant constituents. Raw materials should be stored, measured, and mixed in an area completely isolated from the cooling water systems. Only after the ingredients are made into tile are they insoluble in water. Toxic materials should be eliminated from the tile ingredients.

If possible, contact water cooling operations should be eliminated. If this is not feasible, the contact cooling water should be protected from contamination. Bearing leaks should be controlled and escaping water protected from contact with wax, oils, glue, and other dirt.

If the contact cooling water and the non-contact cooling water that escapes were prevented from becoming contaminated, it would be much easier to treat. This contamination is unnecessary and the resulting process waste water is costly to treat.

TREATMENT TECHNOLOGY

Most asbestos manufacturing plants currently provide some form of treatment of the raw waste waters before discharge to receiving waters. In virtually all cases, this treatment is sedimentation. At several plants, the treatment facilities are small and of simple design. Fortunately the waste solids are dense and almost any period of detention will accomplish major removal of the pollutant load.

Technical Considerations

Sedimentation is the oldest of all treatment unit operations in sanitary engineering practice. It is well understood and its costs, ease of operation, efficiency, and reliability make it ideally suited for industrial application.

Application-

Sedimentation is an appropriate form of treatment for asbestos manufacturing plant waste waters regardless of the plant size and capacity, manufacturing process, or plant and equipment age. Design is based on the hydraulic discharge and plants with smaller effluent volumes can use smaller units. The treatment system can be sized to accommodate surges and peak flows efficiently. Because waste asbestos solids are inert biologically, overdesign does not result in solids management problems.

Land Requirements-

If necessary, complete settling facilities large enough to treat the waste flows from any asbestos manufacturing plant can be placed on an area of 0.1 hectare (0.25 acre) or less. If more land is available, larger units that provide solids storage may be constructed. Such units would result in lower operating costs. This design is especially appropriate for waste waters from asbestos- cement products manufacture because the solids are inert. Solids with significant BOD_5 levels may require more prompt reuse or dewatering and disposal.

The land requirements for asbestos solids disposal are not excessively high. Some plants have disposed of solids within relatively limited boundaries for decades. While this practice results in problems it does serve to indicate that land disposal, if properly carried out as discussed in Section VIII, is an appropriate means of disposing of waste solids from asbestos manufacturing.

Compatibility of Control Measures-

The recommended end-of-pipe technology for the industry is sedimentation, with ancillary operations as necessary. The subsequent control technology recommended is complete recirculation of all process waste waters from all categories of asbestos manufacturing covered by this document. In most cases, complete recycle will require that the save-all system be expanded or supplemented to provide higher quality water for some in-plant uses. The waste water treatment facility could very readily serve this function.

Consequently, the recommended end-of-pipe control technology would represent part of an overall long-term control program to achieve zero discharge of pollutant constituents at most locations.

Product Categories

Control and treatment technologies that are applicable to specific product categories of the asbestos manufacturing industry are described below.

Asbestos-Cement Products (A/C Pipe and A/C Sheet)

The applicable end-of-pipe technology for waste waters from the manufacture of asbestos-cement products, both pipe and sheet, is sedimentation and neutralization. Designs based on total detention periods of 6 to 8 hours or loading levels of 24 cubic meters per day per square meter (600 gallons per day per square foot) of surface area yield effluent suspended solids levels of 30 mg/l or lower.

Neutralization to a pH level of 9.0 or below has been achieved at two locations in the industry by adding sulfuric acid or on-site generated carbon dioxide. At both of these locations, sedimentation precedes and follows neutralization.

The solids removed by the settling units are best dewatered by gravity thickening. They are dense and biochemically inert and are suitable for disposal by proper landfill disposal techniques.

To achieve complete recirculation of process waste waters, surge capacity will have to be added to the water system. A sedimentation unit cannot function in this capacity. A water storage tank or reservoir would be required in the system. With complete recycle, the neutralization operation will not be required. Its function is to protect the receiving water. High pH levels are not a problem in the manufacture of asbestos-cement products. As noted in a previous section, additional scale control measures are necessary when complete recycle is implemented.

As noted above, complete recirculation of asbestos-cement sheet process water has been demonstrated partially. Problems with product strength have been reported in one effort to completely recycle waste water from asbestos-cement pipe manufacture. Additional research is needed to achieve this level of control.

Asbestos Paper--

The applicable end-of-pipe technology for waste waters from the manufacture of asbestos paper is sedimentation preceded, as necessary, by grit removal and coagulation with polyelectrolytes. This treatment has been demonstrated at three or more locations. Units designed for a loading of 24 cubic meters per day per square meter (600 gallons per day per square foot) have achieved suspended solids and BOD_5 reductions to 25 mg/l or less.

Most of the settled solids as well as part of the clarified water should be recycled from the settling unit to the manufacturing process at paper plants. The waste solids, which are normally kept to a minimum, may be stored for later use or dewatered for land disposal with the grit. Waste solids result, in part, from the incompatibility of certain synthetic binders.

To achieve complete recycle of all process waste waters at asbestos paper plants, surge capacity will be required. A water storage tank will be required because the sedimentation unit cannot provide this function.

As noted above, complete recirculation of asbestos paper process water has been demonstrated partially when starch is used as the binder. Additional research is needed to achieve this level of control when using elastomeric binders.

Asbestos Millboard--

As discussed above under In-Plant Controls, the applicable control measure for asbestos millboard plants is complete recycle of all process waste waters. No end-of-pipe technology is specifically required if the plant's save-all capacity is adequate. Unlike settling tanks, save-alls can provide surge capacity.

Waste solids will normally be generated only when the plant is shut down. These will require dewatering and transportation to a land disposal site. Since asbestos millboard manufacturing operations are located in plants that make other asbestos products, the best means of solids handling and disposal will be dependent on the methods used for solids from the other product lines.

Asbestos Roofing--

The applicable end-of-pipe technology for asbestos roofing waste waters is sedimentation with skimming or filtration to remove insoluble materials. Properly designed and operated facilities should reduce the suspended solids levels to 15 mg/l and COD to 20 mg/l or less. If the organic materials are not adequately removed, further treatment, possibly by activated carbon adsorption, will be required. There is, at present, no information available by which to assess the suitability or efficiency of such treatment for these wastes. Information is lacking on the nature of the dissolved organics in waste waters from asbestos roofing manufacture.

To completely eliminate the discharge of pollutant constituents will require that the contaminated cooling water that constitutes the process waste water be treated, cooled, and reused. As noted above, the precise type and extent of treatment required is not known due to lack of information.

An alternative solution would be the elimination of contact cooling and confinement of leaks so that the water remains uncontaminated.

Asbestos Floor Tile-

The applicable end-of-pipe technology for floor tile manufacturing waste waters is sedimentation with coagulation and skimming to remove suspended solids. It is believed that the high COD levels associated with some tile plant wastes are caused by insoluble materials. Properly designed and operated facilities should reduce suspended solids levels to 30 mg/l and COD to 75 mg/l or less.

The wastes from different tile plants are somewhat different and the precise technology required to achieve these levels cannot be predicted. At present, treatment beyond plain sedimentation and skimming is not practiced by the industry. Sorption on activated carbon following filtration should remove soluble organic materials to an acceptable level.

Complete elimination of the discharge of pollutants will necessitate either cooling and reuse, or the use of non-contact cooling water systems. No information is available by which to determine the nature of the treatment best suited for the former method.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

An analysis of the estimated costs and pollution reduction benefits of alternative treatment and control technologies applicable to the asbestos manufacturing industry is given in this section.

The cost estimates were developed using data from various sources, including that available from individual manufacturing plants, contractor's files, and the general information in Reference 13,17,19,and 20. The data supplied by industry were limited in scope and applicability. Some of the costs were for treatment systems or designs that were inadequate or inappropriate for achieving the recommended effluent limitations. At a few plants, the treatment facilities were either so old or of such simple design that the cost information had little value.

REPRESENTATIVE PLANTS

The representative plants used to develop treatment cost information were selected because of the relatively high quality of the treatment facilities, the quantity of waste water discharged, the availability of cost data, and the adequacy of verified information about the effectiveness of the treatment facility. The plants used typical, standard manufacturing processes and incorporated some of the in-plant controls described in Section VII. The waste flows were selected as being typical for the larger plants in the category or subcategory. In this regard, the flows used for sizing the treatment facilities upon which the cost estimates were based were not necessarily the average flows at the representative plants.

The end-of-pipe control technologies were designed, for cost purposes, to require minimal space and land area. It is believed that, at most plants, no additional land would be required. At locations with more land available, larger, more economical facilities of somewhat different design, but equal efficiency, could be used.

In summary, the cost information is intended to apply to most plants in the category of subcategory. Differences in age or size of production facilities, level of implementation of in-plant controls, manufacturing process, and local non-water quality environmental aspects all reduce to one basic variable, the volume of waste water discharged.

The representative asbestos manufacturing plants used for developing cost estimates for the product categories and subcategories are described in Table 3. As noted above, age and size factors do not significantly influence costs.

COST INFORMATION

The investment and annual costs associated with the alternative control technologies for the product categories, as well as the effluent quality associated with each alternative, are summarized in Table 4 through 9. All costs are reported in August, 1971, dollars.

Investment Costs

Investment costs are defined as the capital expenditures required to bring the treatment or control technology into operation. Included, as appropriate, are the costs of excavation, concrete, mechanical and electrical equipment installed, and piping. An amount equal to from 15 to 25 percent of the total of the above was added to cover engineering design services, construction supervision, and related costs. The lower figure was used for larger facilities. Because most of the control technologies involved external, end-of-plant systems, no cost was included for lost time due to installation. It is believed that the interruptions required for installation of control technologies can be coordinated with normal plant shut-down and vacation periods in most cases. As noted above, the control facilities were estimated on the basis of minimal space requirements. Therefore, no additional land, and, hence no cost, would be involved for this item.

Capital Costs

The capital costs are calcualted, in all cases, as 8 percent of the total investment costs. Consultations with representative of industry and the financial community led to the conclusion that, with the limited data available, this estimate was reasonable for this industry.

Depreciation

Straight-line depreciation for 20 years, or 5 percent of the total investment cost, is used in all cases.

Operation and Maintenance Costs

Operation and maintenance costs include labor, materials, solid waste disposal, effluent monitoring, added administrative expenses, taxes, and insurance. When the control technology involved water recycling, a credit of $0.30 per 1000 gallons was applied to reduce the operation and maintenance costs. Manpower requirements were based upon information supplied by the representative plants as far as possible. A total salary cost of

TABLE 3

REPRESENTATIVE MANUFACTURING PLANTS USED IN
DEVELOPING COST INFORMATION

Product	Daily Production		Wastewater Flow			
			Actual		Design	
	kkg	(Tons)	cu m/day	(mgd)	cu m/day	(mgd)
Asbestos-Cement Pipe	145	160	2,100	0.56	1,990	(0.50)
Asbestos-Cement Sheet	109	(120)	650	(0.17)	470	(0.125)
Asbestos Paper	64	(70)	2,700	(0.72)	1,990	(0.50)
Asbestos Millboard	13.5	(15)	680	(0.18)	380	(0.10)
Asbestos Roofing	650	(720)	1,400	(0.37)	1,500	(0.40)
Asbestos Floor Tile	700,000 pc		1,600	(0.43)	1,500	(0.40)

*Design flow used in developing cost estimates

$10 per man-hour was used in all cases. The costs of chemicals used in treatment were added to the costs of materials used for maintenance and operation.

The costs of solid waste handling and disposal were based primarily upon information supplied by the representative plants. No useful information was available for the costs of solid waste disposal for millboard and roofing manufacture.

Energy and Power Costs

Power costs were estimated on the basis of $0.025 per kilowatt-hour.

TREATMENT OR CONTROL TECHNOLOGIES WITH COSTS

Asbestos-Cement Pipe

Alternative A - No Waste Treatment or Control

Effluent waste load is estimated to be 3.1 kg/kkg (6.3 lb/ton) of suspended solids, 4.4 kg/kkg (8.8 lb/ton) of caustic (hydroxide) alkalinity, and 6.3 kg/kkg (12.6 lb/ton) of dissolved solids for the selected typical plant at this minimal control level. The pH of the untreated waste is 12.0. In-plant use of save-alls is assumed, as this is universally practiced in the industry.

Costs. None.

Reduction Benefits. None.

Alternative B - Sedimentation of Process Wastes

This alternative includes settling of all process waste waters. Some form of sedimentation is applied at almost all plants in the industry. Costs include land disposal of dewatered sludge. Effluent suspended solids load estimated to be 0.19 kg/kkg (0.38 lb/ton). Alkalinity,
pH, and dissolved solids remain high.

Costs. Investment costs are approximately $124,000.

Reduction Benefits. Effluent suspended solids reduction of approximately 94 percent.

Alternative C - Sedimentation and Neutralization of Process Wastes

This alternative includes settling of all process waste waters before and after neutralization to pH 9.0 or below. This alternative is practiced presently by about 30 percent of the pipe plants. Effluent suspended solids load of less than 0.19

kg/kkg (0.38 lb/ton), caustic alkalinity removed, and dissolved solids reduced somewhat.

Costs. Incremental costs are approximately $77,000 over Alternative B; total costs are $201,000.

Reduction Benefits. Reduction of effluent suspended solids of at least 95 percent, caustic alkalinity of almost 100 percent, and an indeterminate reduction in dissolved solids.

Alternative D - Complete Recycle of Process Water

This alternative includes complete recycle of all process power wastewaters back into the manufacturing processes and other in-plant uses. Fresh water taken into plant equals quantity leaving in wet product and other evaporative losses. Complete control of pollutant constituents without discharge is effected. No plant making only pipe presently recycles all of the process wastes.

Costs. Incremental costs are approximately $104,000 over Alternative C; total costs are $305,000.

Reduction Benefits. Reduction of all pollutant constituents, including suspended and dissolved solids and alkalinity, of 100 percent.

The annual costs and resulting effluent quality for each of the four treatment alternatives for asbestos-cement pipe are summarized in Table 4. The cost-effectiveness relationship for suspended solids removal is illustrated in Figure 10.

Asbestos-Cement Sheet Products

Alternative A - No Waste Treatment or Control

Effluent waste load is estimated to be 6.5 kg/kkg (13 lb/ton) of suspended solids, 7.5 kg/kkg (15 lb/ton) of caustic (hydroxide) alkalinity, and 8.5 kg/kkg (17 lb/ton) of dissolved solids for the selected typical plant at this minimal control level. The pH of the untreated waste is 11.7 or higher. In-plant use of save-alls is assumed, as this is universally practiced in the industry.

Costs. None. Reduction Benefits. None.

Alternative B - Sedimentation of Process Wastes

This alternative includes settling of all process waste waters. Some form of sedimentation is applied at most plants in the industry. Costs include land disposal of the dewatered sludge. Effluent suspended solids load estimated to be 0.23 kg/kkg (0.45 lb/ton). Alkalinity, pH, and dissolved solids remain high.

Table 4
TYPICAL PLANT

WATER EFFLUENT TREATMENT COSTS

ASBESTOS MANUFACTURING
Asbestos-Cement Pipe

Treatment or Control Technologies	Alternatives A	B	C	D
Investment*	-	$124	$201	$305
Annual Costs:*				
Capital Costs	-	9.9	16.1	24.4
Depreciation	-	6.2	10.1	15.3
Operating and Maintenance Costs (excluding energy and power costs)	-	63.8	87.8	98.3
Energy and Power Costs	-	2.8	7.0	11.9
Total Annual Cost*	-	82.7	121	149.9

*Costs in thousands of dollars

Effluent Quality:

Effluent Constituents Parameters (Units)	Raw Waste Load	Resulting Effluent Levels			
Suspended Solids - kg/MT	3.1	do	0.19	0.19	0
Caustic Alkalinity - kg/MT	4.4	do	4.4	0	0
pH	12	do	12	9.0	0
Dissolved Solids - kg/MT	6.3	do	6.3	6.3-	0
Suspended Solids - mg/1	500	do	30	30	0
Caustic Alkalinity - mg/1	700	do	700	0	0
Dissolved Solids - mg/1	1000	do	1000	1000-	-

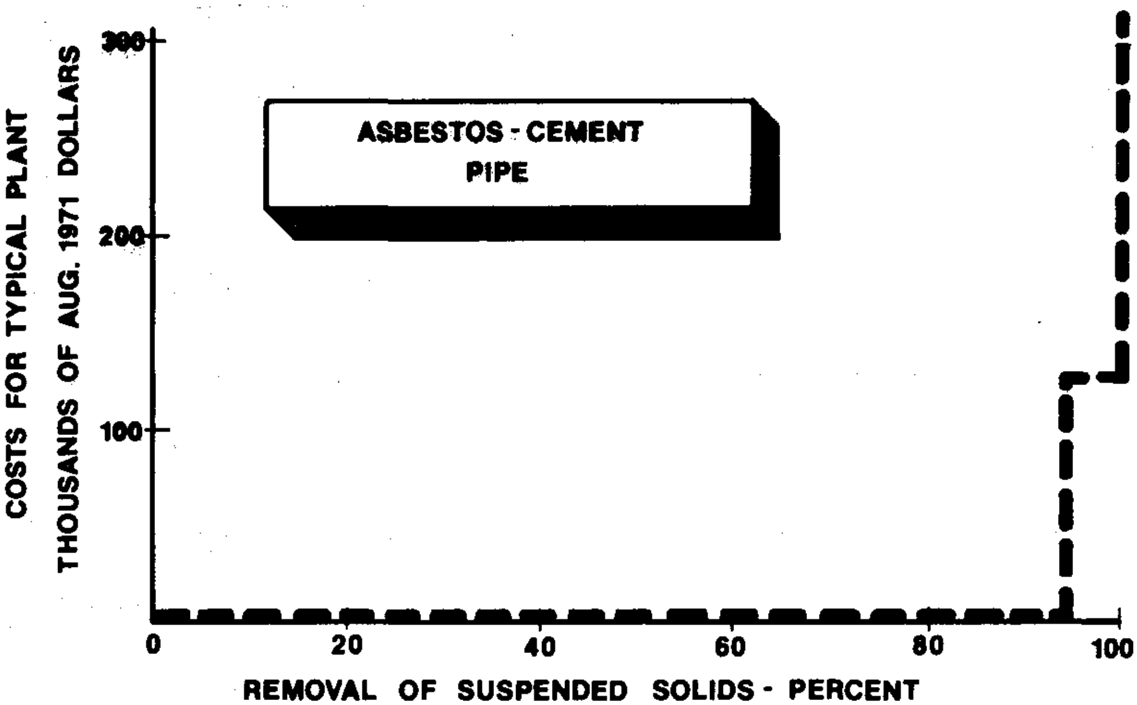

ASBESTOS - CEMENT
PIPE
COSTS FOR TYPICAL PLANT
THOUSANDS OF AUG. 1971 DOLLARS
300
200
100
0
20
40
60
80
100
REMOVAL OF SUSPENDED SOLIDS - PERCENT

Figure 10

Costs. Investment costs are approximately $56,000.

Reduction Benefits. Effluent suspended solids reduction of approximately 96 percent.

Alternative C - Sedimentation and Neutralization of Process Water

This alternative includes settling of all process waste waters before and after neutralization to pH 9.0 or below. This alternative is used by 10 percent or less of the sheet plants. Effluent suspended solids load of less than 0.23 kg/kkg (0.45 lb/ton), caustic alkalinity removed, and dissolved solids reduced somewhat.

Costs. Incremental costs are approximately $36,000 over Alternative B; total costs are $92,000.

Reduction Benefits. Reduction of effluent suspended solids of at least 96 percent, caustic alkalinity of almost 100 percent, and an indeterminate reduction in dissolved solids.

Alternative D - Complete Recycle of Process Water

This alternative includes complete recycle of all process waste waters back into the manufacturing processes or other in-plant uses. Fresh water taken into plant equals quantity leaving in wet product and other evaporative losses. Complete control of pollutant constituents without discharge is effected. One sheet plant is known to accomplish complete recycle during routine operation.

Costs. Incremental costs are approximately $59,000 over Alternative C; total costs are $151,000.

Reduction Benefits. Reduction of all pollutant constituents, including suspended and dissolved solids and alkalinity, of 100 percent.

The annual costs and resulting effluent quality for each of the four technology or control alternatives for asbestos-cement sheet products are presented in Table 5. The cost-effectiveness relationship for suspended solids removal is illustrated in Figure 11.

Asbestos Paper (Starch and Elastomeric)

Alternative A - No Waste Treatment or Control

Effluent waste load is estimated to be 9.5 kg/kkg (19 lb/ton) of suspended solids, 1.5 kg/kkg (3 lb/ton) of BOD_5, and 16.5 kg/kkg (33 lb/ ton) of dissolved solids for the selected typical plant at this minimal control level. In-plant use of save-alls is assumed, as this is universally practiced in the industry.

Table 5
TYPICAL PLANT

WATER EFFLUENT TREATMENT COSTS

ASBESTOS MANUFACTURING
Asbestos-Cement Sheet

Treatment or Control Technologies	Alternatives A	B	C	D
Investment*	-	$56	$92	$151
Annual Costs:*				
Capital Costs	-	4.5	7.3	12.1
Depreciation	-	2.8	4.6	7.5
Operating and Maintenance Costs (excluding energy and power costs)	-	41.4	53.3	92.4
Energy and Power Costs	-	2.8	4.2	7.0
Total Annual Cost*	-	51.5	69.4	119.0

Effluent Quality:

Effluent Constituents Parameters (Units)	Raw Waste Load	Resulting Effluent Levels			
Suspended Solids - kg/MT	6.5	do	0.23	0.23	0
Caustic Alkalinity - kg/MT	7.5	do	7.5	0	0
pH	11.7	do	11.7	9.0	0
Dissolved Solids - kg/MT	8.5	do	8.5	8.5-	0
Suspended Solids - mg/1	850	do	30	30	0
Caustic Alkalinity - mg/1	1000	do	1000	0	0
Dissolved Solids - mg/1	1150	do	1150	1150-	0

*Costs in thousands of dollars

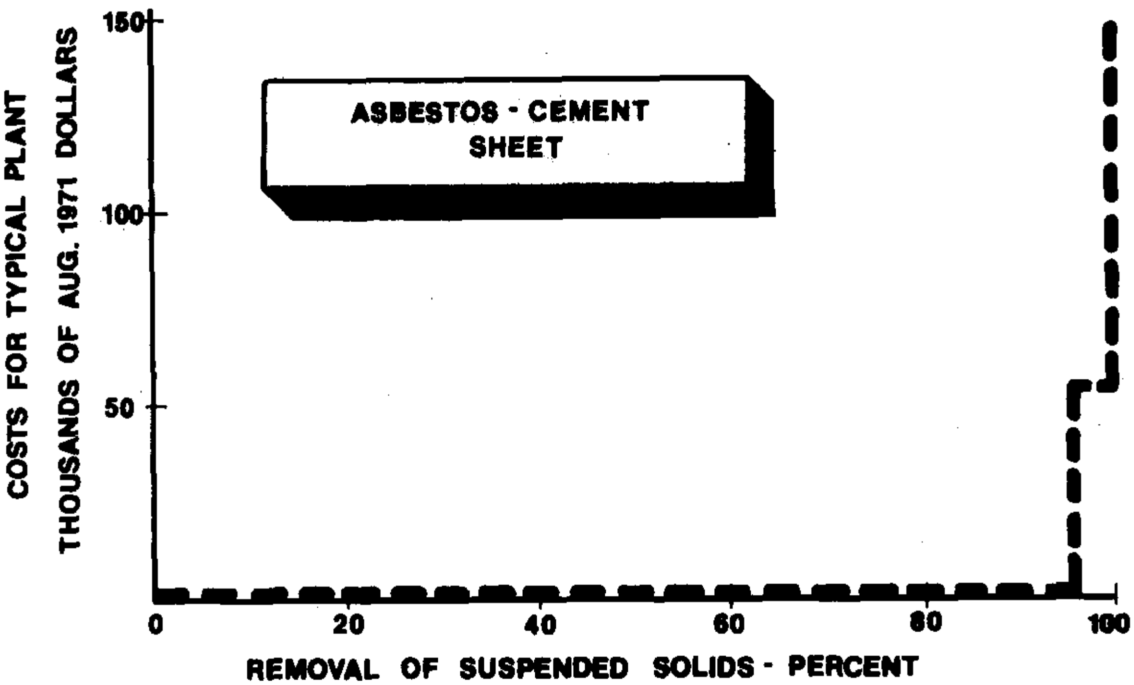

ASBESTOS - CEMENT
SHEET
COSTS FOR TYPICAL PLANT
THOUSANDS OF AUG. 1971 DOLLARS
150
100
50
0
20
40
60
80
100
REMOVAL OF SUSPENDED SOLIDS - PERCENT

Figure 11

Costs. None.

Reduction Benefits. None.

Alternative B - Sedimentation of Process Wastes

This alternative includes settling of all process waste waters. Some form of sedimentation is applied at approximately 70 percent of plants in the industry. Costs include land disposal of dewatered sludge. Effluent load estimated to be 0.35 kg/kkg (0.7 lb/ton) of suspended solids and of BOD_5 and 16.5 kg/kkg (33 lb/ton) of dissolved solids.

Costs. Investment costs are approximately $237,000.

Reduction Benefits. Estimated reduction of effluent solids of 96 percent and BOD_5 of 75 percent. Dissolved solids remain unchanged.

Alternative C - Complete Recycle of Process Water

This alternative includes complete recycle of all process waste waters back into the manufacturing processes and other in-plant uses. Fresh water taken into plant equals quantity leaving in wet product and other evaporative losses. Complete control of pollutant constituents without discharge is effected. One paper plant is known to achieve complete recycle when using starch binder under routine conditions.

Costs. Incremental costs are approximately $57,000 over Alternative B; total costs are $294,000.

Reduction Benefits. Reduction of all pollutant constituents, including suspended and dissolved solids and BOD_5, of 100 percent.

The estimated annual costs and effluent quality for each of the alternatives for asbestos paper manufacturing waste waters are given in Table 6. The cost-effectiveness curve for suspended solids removal from asbestos paper waste waters is given in Figure 12.

Asbestos Millboard

Alternative A - No Waste Treatment or Control

Effluent waste load is estimated to be 1.8 kg/kkg (3.6 lb/ton) of suspended solids and 0.25 kg/kkg (0.5 lb/ton) of BOD_5 for the selected typical plant at this minimal control level. In-plant use of save-alls is assumed, as this is universally practiced in the industry.

Costs. None. Reduction Benefits. None.

Table 6
TYPICAL PLANT

WATER EFFLUENT TREATMENT COSTS

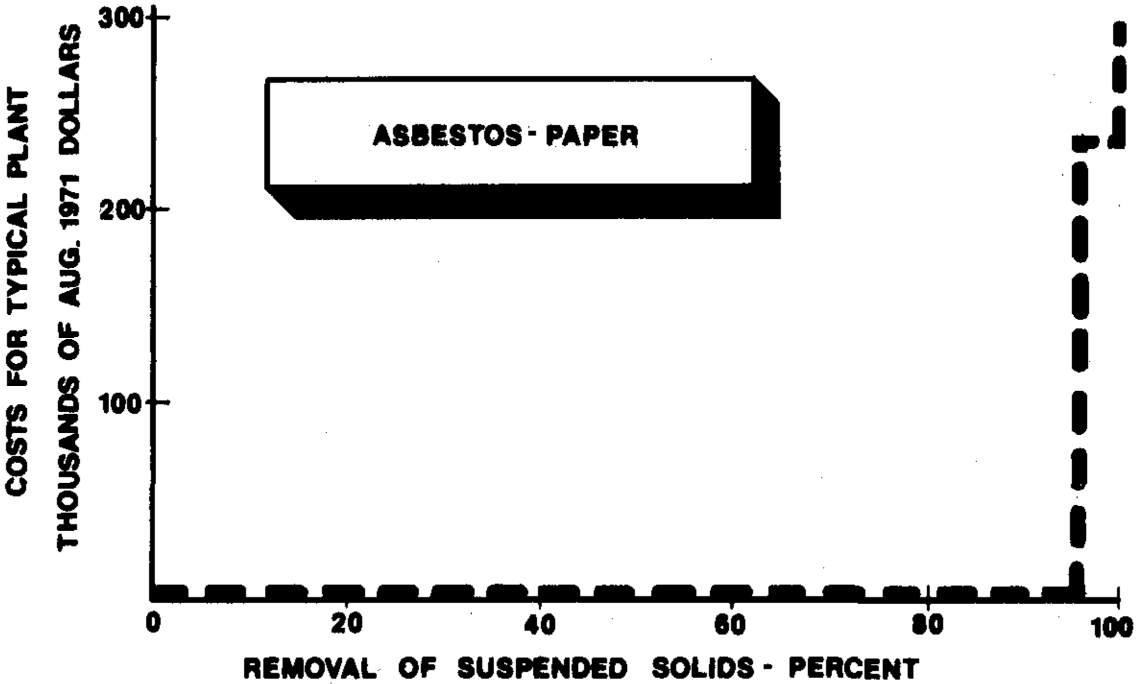
ASBESTOS MANUFACTURING
Asbestos Paper

Treatment or Control Technologies	Alternatives A	B	C
Investment*	-	$237	$294
Annual Costs:*			
Capital Costs	-	19	24
Depreciation	-	12	15
Operating and Maintenance Costs (excluding energy and power costs)	-	16	44
Energy and Power Costs	-	16	16
Total Annual Cost*	-	63	99

*Costs in thousands of dollars

Effluent Quality:

Effluent Constituents Parameters (Units)	Raw Waste Load	Resulting Effluent Levels		
Suspended Solids - kg/MT	9.5	do	0.35	0
BOD (5-day) - kg/MT	1.5	do	0.35	0
Dissolved Solids - kg/MT	16.5	do	16.5	0
Suspended Solids - mg/l	700	do	25	0
BOD (5-day) - mg/l	110	do	25	0
Dissolved Solids - mg/l	1200	do	1200	0



COSTS FOR TYPICAL PLANT
THOUSANDS OF AUG. 1971 DOLLARS
300
200
100
ASBESTOS - PAPER
0
20
40
60
80
100
REMOVAL OF SUSPENDED SOLIDS - PERCENT

Figure 12

Alternative B - Sedimentation of Process Wastes

This alternative includes settling of all process waste waters. Some form of sedimentation is applied to at least 40 percent of the plants. Costs include disposal of sludge. Effluent load estimated to be 0.8 kg/kkg (1.6 lb/ton) of suspended solids and 0.2 kg/kkg (0.4 lb/ton) of BOD5.

Costs. Investment costs are approximately $40,000.

Reduction Benefits. Estimated reduction of effluent suspended solids of 55 percent and BOD5 of 20 percent.

Alternative C - Complete Recycle of Process Water

This alternative includes complete recycle of all process waste waters back into the manufacturing process and other in-plant uses. Fresh water taken into plant equals the quantity in wet product. Complete control of pollutant constituents without discharge is effected. One millboard plant is known to achieve complete recycle most of the time.

Costs. Incremental costs are approximately $12,000 over Alternative B; total costs are $52,000.

Reduction Benefits. Reduction of suspended solids, BOD5, and all other pollutant constituents of 100 percent.

The annual costs and resulting effluent quality for the treatment or control technology alternatives for asbestos millboard are summarized in Table 7. The cost-effectiveness relationship for suspended solids removal is illustrated in Figure 13.

Asbestos Roofing

Alternative A - No Waste Treatment or Control

Effluent waste load is estimated to be 0.06 kg/kkg (0.12 lb/ton) of suspended solids, 0.003 kg/kkg (0.006 lb/ton) of BOD5, and 0.008 kg/kkg (0.016 lb/ton) of COD for the selected typical plant at this minimal control level.

Costs. None.

Reduction Benefits. None.

Alternative B - Sedimentation of Process Wastes (Contaminated Cooling Water)

This alternative includes settling of all process waste waters (contaminated cooling water) with skimming or filtration as necessary to remove suspended matter. Effluent load estimated to be 0.006 kg/kkg (0.012 lb/ton) of suspended solids. BOD5 and COD waste loads remain the same as Alternative A.

Table 7
TYPICAL PLANT

WATER EFFLUENT TREATMENT COSTS

ASBESTOS MANUFACTURING
Asbestos Millboard

Treatment or Control Technologies	A	B	C
		Alternatives	
Investment*	-	$40	$52
Annual Costs:*			
Capital Costs	-	3.2	4.2
Depreciation	-	2.0	2.6
Operating and Maintenance Costs (excluding energy and power costs)	-	31.0	24.3
Energy and Power Costs	-	5.0	7.0
Total Annual Costs*	-	41.2	38.1

*Costs in thousands of dollars

Effluent Quality:

Effluent Constituents Parameters (Units)	Raw Waste Load	Resulting Effluent Levels		
Suspended Solids - kg/MT	1.8	do	0.8	0
BOD (5-day) - kg/MT	0.25	do	0.2	0
Suspended Solids - mg/l	35	do	15	0
BOD (5-day) - mg/l	5	do	4	0

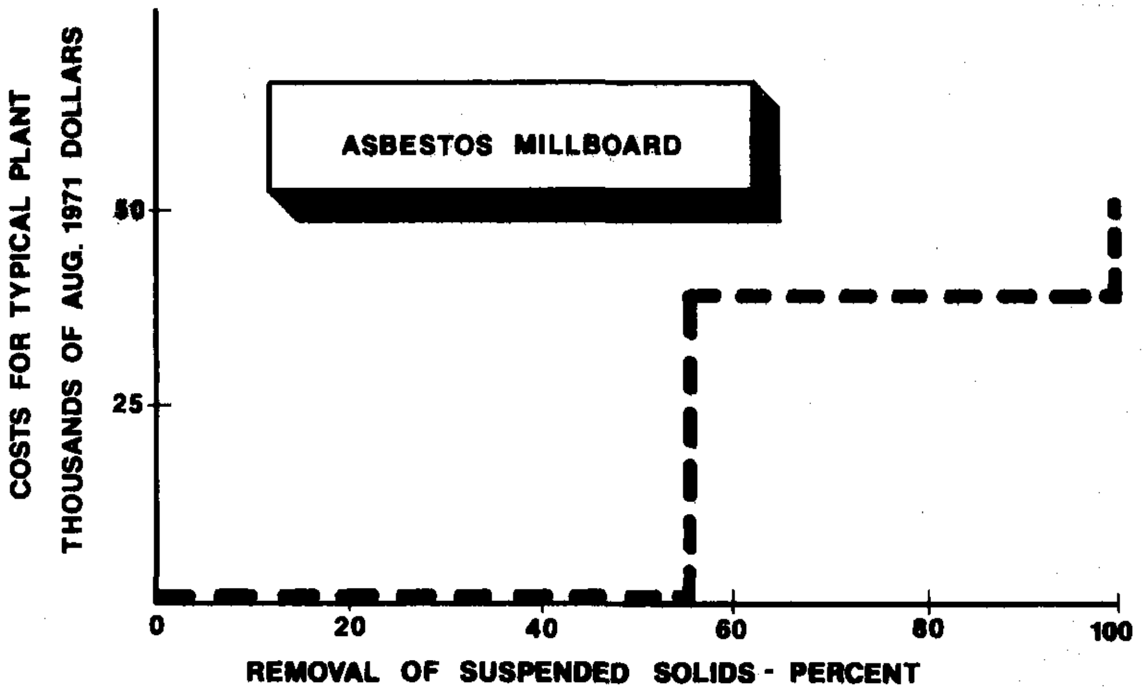

ASBESTOS MILLBOARD
COSTS FOR TYPICAL PLANT
THOUSANDS OF AUG. 1971 DOLLARS
50
25
0
20
40
60
80
100
REMOVAL OF SUSPENDED SOLIDS - PERCENT

Figure 13

Costs. Investment costs are approximately $24,000.

Reduction Benefits. Estimated reduction of effluent suspended solids of 90 percent.

Alternative C - Complete Recycle of Process Water

This alternative includes treatment, cooling, and reuse of process waste water (contaminated cooling water). No process waste waters are discharged and complete control of pollutant constituents is effected.

Costs. Incremental costs are approximately $24,000 over Alternative B; total costs are $48,000.

Reduction Benefits. Reduction of suspended solids, BOD5, and COD and all other pollutant constituents of 100 percent.

The annual costs and effluent quality associated with each of the treatment or control alternatives for asbestos roofing are given in Table 8. The cost-effectiveness curve for suspended solids removal for asbestos roofing is shown in Figure 14.

Asbestos Floor Tile

Alternative A - No Waste Treatment or Control

Effluent waste load is estimated to be 0.18 kg (0.38 lb) of suspended solids, 0.017 kg (0.04 lb) of BOD5, and 0.34 kg (0.75 lb) of COD per 1,000 pieces of tile manufactured at the selected typical plant at this minimal control level.

Costs. None.

Reduction Benefits. None.

Alternative B - Coagulation and Sedimentation of Process Wastes (Contaminated Cooling Water)

This alternative includes polyelectrolyte coagulation and sedimentation with skimming as necessary to remove suspended matter. The percentage of tile plants applying this alternative is not known, but is expected to be less than 25 percent. The effluent load is estimated to be 0.04 kg (0.08 lb) of suspended solids and 0.09 kg (0.19) of COD per 1,000 pieces of tile manufactured. The BOD5 load may be reduced somewhat.

Costs. Investment costs are approximately $52,000.

Table 8
TYPICAL PLANT

WATER EFFLUENT TREATMENT COSTS

ASBESTOS MANUFACTURING
Asbestos Roofing

Treatment or Control Technologies	Alternatives A	B	C
Investment*	-	$24	$48
Annual Costs:*			
Capital Costs	-	2.0	4.0
Depreciation	-	1.2	2.4
Operating and Maintenance Costs (excluding energy and power costs)	-	6.0	0
Energy and Power Costs	-	1.3	2.0
Total Annual Costs*	-	10.0	8.4

*Costs in thousands of dollars

Effluent Quality:

Effluent Constituents Parameters (Units)	Raw Waste Load	Resulting Effluent Levels		
Suspended Solids - kg/MT	0.06	do	0.006	0
BOD (5-day) - kg/MT	0.003	do	0.003	0
COD - kg/MT	0.008	do	0.008	0
Suspended Solids - mg/l	150	do	15	0
BOD (5-day) - mg/l	6	do	6	0
COD - mg/l	20	do	20	0

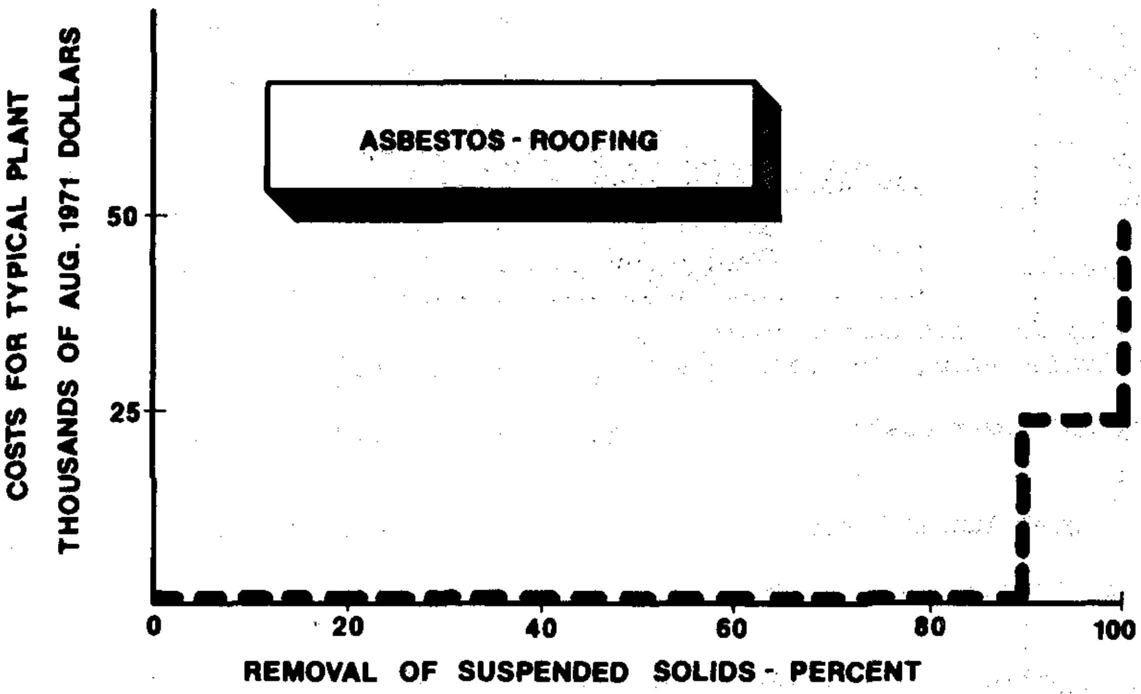

ASBESTOS - ROOFING
COSTS FOR TYPICAL PLANT
THOUSANDS OF AUG. 1971 DOLLARS
50
25
0
20
40
60
80
100
REMOVAL OF SUSPENDED SOLIDS - PERCENT

Figure 14

Reduction Benefits. Estimated reduction of effluent suspended solids of 80 percent and COD of 75 percent.

Alternative C - Complete Recycle of Process Water (Contaminated Cooling Water)

This alternative includes additional treatment by filtration, cooling, and reuse of process waste waters (contaminated cooling water). No process wastes are discharged and complete control of pollutant constituents is effected.

Costs. Incremental costs are approximately $58,000 over Alternative B; total costs are $110,000.

Reduction Benefits. Reduction of suspended solids, BOD_5, and COD and all other pollutant constituents of 100 percent.

The annual costs and resulting effluent quality for each of the three treatment or control technology alternatives for asbestos floor tile are summarized in Table 9.

The cost-effectiveness curve for suspended solids removal from waste waters from floor tile manufacturing is illustrated in Figure 15.

ENERGY REQUIREMENTS OF TREATMENT AND CONTROL TECHNOLOGIES

The energy required to implement in-plant control measures at a typical asbestos manufacturing plant is 20 kw (25 Hp) or less. The energy requirement is primarily for pumping to recycle and reuse water.

The energy requirements of the end-of-pipe treatment technology are not high for a typical plant. No aeration or heating operations are involved. The single largest energy use would be a centrifuge for dewatering waste solids from a paper or millboard plant. This would be used only intermittently and would require no more than 30 to 40 kw when running. The motors for the sludge mechanisms in clarifiers are normally small, 5 kw or less, and the pumping energy requirements would be similar in magnitude to those for in-plant controls.

It is estimated that the total energy requirements for in-plant control and end-of-pipe treatment technology at a typical asbestos manufacturing plant would not exceed 50 kw on a sustained basis.

No information was provided by the industry relative to the energy requirements of individual manufacturing plants. Most

Table 9
TYPICAL PLANT

WATER EFFLUENT TREATMENT COSTS

ASBESTOS MANUFACTURING
Asbestos Floor Tile

Treatment or Control Technologies	Alternatives A	B	C
Investment*	-	$52	$110
Annual Costs:*			
Capital Costs	-	4.2	8.8
Depreciation	-	2.6	5.5
Operating and Maintenance Costs (excluding energy and power costs)	-	11.0	10.8
Energy and Power Costs	-	1.8	3.0
Total Annual Cost*	-	19.6	28.1

*Costs in thousands of dollars

Effluent Quality:

Effluent Constituents Parameters (Units)	Raw Waste Load	Resulting Effluent Levels		
Suspended Solids - kg/1000 pc	0.18	do	0.04	0
BOD (5-day) - kg/1000 pc	0.017	do	0.017-	0
COD - kg/1000 pc	0.34	do	0.09	0
Suspended Solids - mg/l	150	do	30	0
BOD (5-day) - mg/l	15	do	15-	0
COD - mg/l	280	do	75	0

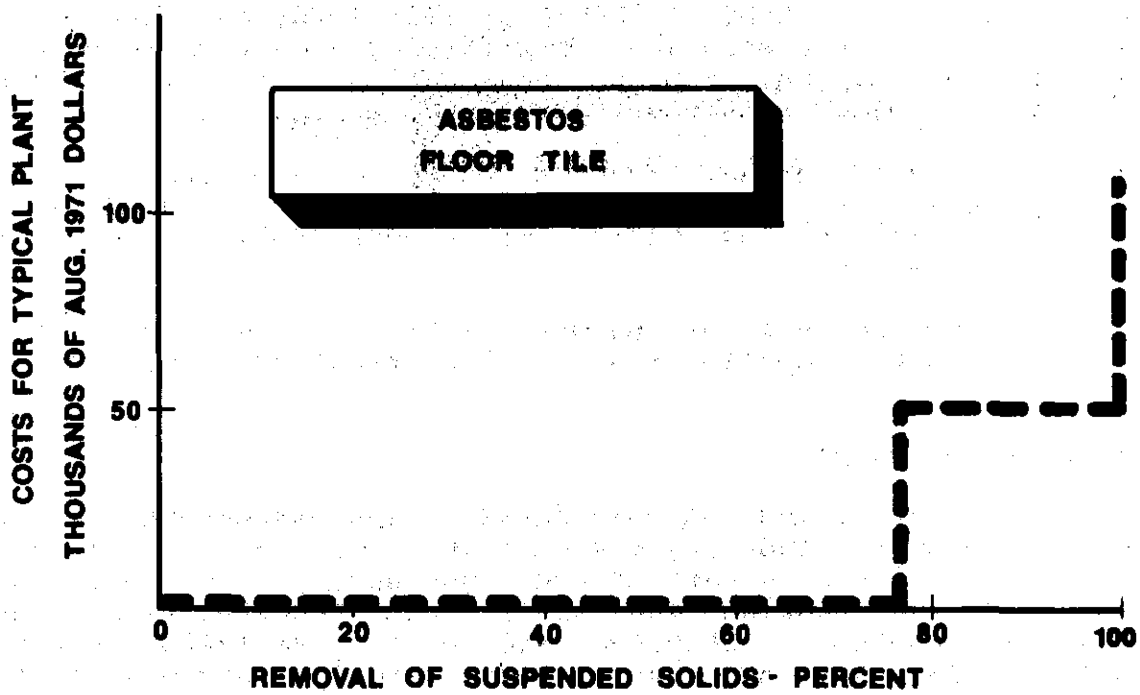

ASBESTOS
FLOOR TILE
COSTS FOR TYPICAL PLANT
THOUSANDS OF AUG. 1971 DOLLARS
100
50
0
20
40
60
80
100
REMOVAL OF SUSPENDED SOLIDS - PERCENT

Figure 15

involve steam generation for heating, for autoclaves, and for product drying. The additional energy required to implement the control and treatment technologies is estimated to be less than 10 percent of the requirements of the manufacturing and associated operations.

NON-WATER QUALITY ASPECTS OF TREATMENT AND CONTROL TECHNOLOGIES

Air Pollution

The only significant potential air pollution problem associated with the application of waste water treatment and control technologies at a typical asbestos manufacturing plant is the release of asbestos fibers and other particulates from improperly managed solid residues. Exposed accumulations of dried solids may serve as sources of air emissions upon weathering.

The biodegradable organic matter content of asbestos solids is low or non-existent. The solids do not undergo appreciable microbial breakdown and there are no odor problems associated with asbestos wastes.

There are no unusual or uncontrollable sources of noise associated with application of the treatment and control technologies.

Solid Waste Disposal

Solid waste control must be considered. The waterborne wastes from the asbestos industry may contain a considerable volume of asbestos particles as a part of the suspended solids pollutant except for the roofing and floor tile subcategories. Best practicable control technology and best available control technology as they are known today require disposal of the pollutants removed from waste waters in this industry in the form of solid wastes and liquid concentrates. In some cases these are non-hazardous substances requiring only minimal custodial care. However, some constituents may be hazardous and may require special consideration. In order to ensure long term protection of the enviornment from these hazardous or harmful constituents, special consideration of disposal sites must be made. All landfill sites where such hazardous wastes are disposed should be selected so as to prevent horizontal and vertical migration of these contaminants to ground or surface waters. In cases where geologic conditions may not reasonably ensure this, adequate legal and mechanical precautions (e.g. impervious liners) should be taken to ensure long term protection to the environment from hazardous materials. Where appropriate the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of legal jurisdiction.

Consideration should also be given to the manner in which the solid waste is transferred to a industries waste disposal area.

Solids collected in clarifiers, save-alls or other sedimentation basins should first be dewatered to sludge consistency. Transportation of this asbestos containing sludge should be in a close container or truck in the damp state so as to minimize air dispersal due to blowing. Precautions should also be taken to minimize air dispersal when the sludge is deposited at the waste disposal areas.

The quantities of solids associated with treatment and control of waste waters from paper, millboard, roofing, and floor tile manufacturing are extremely small. For example, the reported volume of dewatered waste solids from a paper plant is 1.5 cu m (2 cu yd) per month. Solids are wasted only when elastomeric binders are being used, which is 25 to 35 percent of the time. Another example is that provided by one of the larger floor tile plants in the country. The sludge and skimmings from the sedimentation unit amount to about 625 liters (165 gallons) per week. Unlike other asbestos manufacturing wastes, this material is highly organic and is disposed of by a commercial firm that incinerates it. The treatment facility at this plant is not highly efficient, but is believed to capture at least 50 percent of the waste solids.

Contrary to the above categories, the waste solids associated with asbestos-cement product manufacture are significant in volume. The reported losses at one pipe plant are in the order of 5 to 10 percent of the weight of the raw materials. The losses of asbestos fibers are kept to a minimum in this industry, to 1 percent or less, and the fiber content of the waste solids is low. The solids have no salvage or recovery value.

In summary, the solid wastes disposal associated with the application of treatment and control technologies in the asbestos manufacturing industry does not present any serious technical problems. The wastes are amenable to proper landfill disposal. Full application of control measures and treatment technology will not result in major increases at most plants. In many cases, complete recycle will result in lower losses of solids.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS GUIDELNES

INTRODUCTION

The effluent limitations which must be achieved July 1, 1977 are to specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available. Best Practicable Control Technology Currently Available is generally based upon the average of the best existing performance by plants of various sizes, ages, and unit processes within the industrial category or subcategory. This average is not based upon a broad range of plants within the asbestos manufacturing industry, but based upon performance levels achieved by exemplary plants.

Consideration must also be given to:

a. The total costs of application of technology in relation to the effluent reduction benefits to be achieved from such application;

b. energy requirements;

c. non-water quality environmental impact;

d. the size and age of equipment and facilities involved;

e. the processes employed;

f. processes changes; and,

g. the engineering aspects of the application of various types of control techniques.

Also, Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of a manufacturing process, but also includes the control technologies within the process itself when the latter are considered to be normal practice within an industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction or installation of the control facilities.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Based on the information contained in Sections III through VIII of this document, a determination has been made of the degree of effluent reduction attainable through the application of the Best Pollution Control Technology Currently Available for the asbestos manufacturing industry. The effluent reductions are summarized here.

Suspended Solids

The principal pollutant constituent in waste waters from the manufacture of asbestos-cement products and asbestos paper and millboard is suspended solids. Application of this control technology will reduce suspended solids levels by at least 95 percent.

The relatively lesser suspended solids from asbestos roofing and floor tile manufacture will be reduced by 90 and 80 percent, respectively, by the application of this control technology.

Caustic Alkalinity

Waste waters from asbestos-cement product manufacture are highly caustic. Application of this control technology will reduce the caustic alkalinity by 100 percent. The pH will be 9.0 or below.

Oxygen Demanding Materials

Waste waters from asbestos paper and floor tile manufacture may contain organic constituents that exert an oxygen demand; BOD_5 or COD in the case of paper wastes and COD in floor tile wastes. Application of this control technology will reduce the oxygen demand by 75 percent.

Dissolved Solids

Asbestos manufacturing may raise the dissolved solids level in water significantly, especially in the case of asbestos-cement products.

Application of this control technology will reduce the dissolved solids by an indeterminate amount. The dissolved solids in the treated effluent will still be relatively high.

Temperature

Asbestos manufacturing operations increase the water temperature to maximum levels of 40 degrees C. Application of this control technology will not result in significant temperature reduction.

IDENTIFICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

In-plant control measures available to the asbestos manufacturing industry will not significantly reduce the level of pollutant constituents in the effluent. Application of such measures may result in economic benefits and reduced end-of-pipe treatment costs.

The Best Practicable Control Technology Currently Available for the categories of the asbestos manufacturing industry is summarized below. There are no limitations on BOD5 and only two subcategories have COD limitations. Treatment in the asbestos industry is mainly sedimentation, the efficiency of which can be adequately monitored using the total suspended solids parameter.

Also, since these limitations are absolute restrictions on pollutants no credit is given for pollutants in waters entering the processes. The BOD5 load in incoming water can be substantial when compared to the BOD5 contributed by the process. This is an additional reason for not including BOD5 in the limitations.

However in the roofing and floor tile subcategories, the major pollutants are organic and must be limited. This is accomplished through sedimentation and skimming. Effluent concentration will be low. Therefore, to allow in these specific cares for a COD credit in incoming waters COD is defined as COD added to the process waste waters. Monitoring will thus obviously entail sampling of water entering the process and exiting the treatment system.

Asbestos-Cement Pipe

The control technology is sedimentation and neutralization of all process waste waters with land disposal of dewatered waste solids. The recommended effluent limitations are as follows:

	Monthly Average		Daily Maximum	
	kg/kkg	(lb/ton	kg/kkg	(lb/ton)
Suspended Solids	0.19	(0.38)	0.57	(1.14)
pH	6.0-9.0		6.0-9.0	

Asbestos-Cement Sheet

The control technology is sedimentation and neutralization of all process waste waters with land disposal of dewatered waste solids. The recommended effluent limitations are as follows:

	Monthly Average kg/kkg	(lb/ton	Daily Maximum kg/kkg	(lb/ton)
Suspended Solids	0.23	(0.45)	0.68	(1.35)
pH	6.0-9.0		6.0-9.0	

Asbestos Paper (Starch Binder)

The control technology is sedimentation, with coagulation if necessary, of all process waste waters with land disposal of dewatered waste solids. The recommended effluent limitations are as follows:

	Monthly Average kg/kkg	(lb/ton	Daily Maximum kg/kkg	(lb/ton)
Suspended Solids	0.35	(0.70)	0.55	(1.10)
pH	6.0-9.0		6.0-9.0	

Asbestos Paper (Elastomeric Binder)

The control technology is sedimentation, with coagulation if necessary, of all process waste waters with land disposal of dewatered waste solids. The recommended effluent limitation are as follows:

	Monthly Average kg/kkg	(lb/ton	Daily Maximum kg/kkg	(lb/ton)
Suspended solids	0.35	(0.70)	0.55	(1.10)
pH	6.0-9.0		6.0-9.0	

Asbestos Millboard

The control technology is no discharge of process waste waters to navigable waters. In a plant that manufactures millboard and other asbestos products, no increase in the limitations should be allowed for the millboard in combined waste streams.

Asbestos Roofing

The control technology is sedimentation, with skimming and ancillary physical treatment operations if necessary, of all process waste waters (contaminated cooling water). The recommended effluent limitations are as follows:

	Monthly Average		Daily Maximum	
	kg/kkg	(lb/ton)	kg/kkg	(lb/ton)
Suspended Solids	0.006	(0.012)	0.010	(0.020)
COD	0.008	(0.016)	0.015	(0.029)
pH	6.0-9.0		6.0-9.0	

Asbestos Floor Tile
The control technology is sedimentation, with skimming if necessary, or other physical treatment of all process waste waters (contaminated cooling water). The recommended effluent limitations are as follows:

	Monthly Average		Daily Maximum	
	kg/Mpc*	(lb/Mpc*)	kg/Mpc*	(lb/Mpc*)
Suspended Solids	0.04	(0.08)	0.06	(0.13)
COD	0.09	(0.18)	0.14	(0.30)
pH	6.0-9.0		6.0-9.0	

*Mpc = 1,000 pieces (12" x 12" x 3/32")

RATIONALE FOR THE SELECTION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Asbestos-Cement Pipe

Sedimentation of process waste waters from asbestos-cement pipe manufacture has been demonstrated to be effective in reducing suspended solids concentrations to acceptable levels. No cheaper alternative technology is available that is as effective as sedimentation. The addition of either acid or carbon dioxide is the most direct and least costly menthod of reducing the pH of the waste waters to acceptable levels.

Costs and Energy Requirements-

The investment costs of implementing this level of control technology are estimated to be $860,000 for all manufacturing facilities in this subcategory. The added annual costs are estimated to be $470,000. The additional energy requirements are estimated to be 37 kw (50 hp) or less for the typical plant. This power requirement represents only a small increment of the total required for manufacturing.

Non-Water Quality Environmental Impact--

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems, either in king or magnitude. The costs of avoiding problems in these areas are not excessive.

Size and Age of Equipment and Facilities--

As noted in Section IV, the size range among asbestos-cement pipe manufacturing facilities is relatively narrow. Differences in size are insufficient to substantiate differences in control technology. This level of control technology is readily applicable to all facilities regardless of the age of the equipment or the structure.

Processes Employed and Process Changes--

All facilities use similar manufacturing processes and produce similar waste water discharges. There is no evidence that operation of any process currently in use will substantially affect capabilities to implement this control technology. The implementation of this control technology does not require in-plant changes or modifications. Major developments in manufacturing processes in the future are not expected. This control technology can be applied so that upsets and other fluctuations in process operations can be accomodated without exceeding the effluent limitations.

Engineering Aspects of Application--

It is estimated that approximately 30 percent of the asbestos-cement pipe manufacturing plants are currently using this control technology. There are no plants making only pipe that achieve a higher level of control. This was judged to be the average of the best technology currently available in this subcategory. It was determined to be an adequate level of control. Most plants in this product subcategory provide some form of sedimentation, without pH adjustment. Most of the treatment facilities will have to upgrade in operations or capacity in order to achieve the elfluent limitations recommended in this document.

Asbestos-Cement Sheet

Sedimentation of process waste waters from the manufacture of asbestos-cement sheet products has been demonstrated to be effective in reducing suspended solids concentrations to acceptable levels. No cheaper alternative control technology is more effective than sedimentation. The addition of either acid or carbon dioxide is widely practiced in other industrial categories to lower the pH of alkaline wastes to acceptable levels. This operation can be applied to wastes from sheet manufacture.

Costs and Engergy Requirements--

The investment costs of implementing this level of control technology are estimated to be $640,000 for all manufacturing facilities in this subcategory. The annual costs are estimated to be approximately $440,000. The additional energy requirements are estimted to be 22 kw (30 hp) or less for the typical plant. This power requirement represents only a small additional increment of the total required for manufacturing.

Non-Water Quality Environmental Impact--

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems either in kind or magnitude. The costs of avoiding problems in these areas are not excessive.

Size and Age of Equipment and Facilites--

As noted in Section IV, the size range among asbestos-cement sheet manufacturing facilities is relatively narrow. Differences in size are insufficient to substantiate differences in control technology. This level of control technology is readily applicable to all facilities regardless of the age of the equipment or the structure.

Processes Employed and Process Changes--

All facilities use similar manufacturing processes and produce a similar waste water discharge. There is no evidence that operation of any process currently in use will substantially affect capabilities to implement this control technology. The implmentation of this control technology does not require in-plant changes or modifications. Major developments in manufacturing processes in the future are not expected. This control technology can be applied so that upsets and other fluctuations in process operations can be accommodated without exceeding the effluent limitations.

Engineering Aspects of Application--

Approximatley 10 percent or less of the asbestos-cement sheet products plants currently use this control technology fully. Most plants in this subcategory provide some form of sedimentation, but without pH adjustment to remove caustic alkalinity. Such control is judged to be inadequate. Attainment of the recommended suspended solids and BOD_5 effluent limitations has been demonstrated by plants within this subcategory. Neutralization of alkaline waste is a treatment technology that has been used successfully in many related industrial applications and can readily be applied in asbestos-cement sheet manufacturing.

Asbestos Paper (Starch and Elastomeric)

Sedimentation, with the use of coagulants in some cases, has been demonstrated to be effective in reducing suspended solids and

BOD_5 concentrations to acceptable levels. No cheaper alternative technology is available that is as effective as sedimentation.

Cost and Energy Requirements--

The investment costs of implementing this control technology are estimated to be $470,000 for all manufacturing facilities in this product subcategory. The added annual costs are estimated to be approximately $125,000. The additional energy requirements are estimated to be 75 kw (100 hp) or less for the typical asbestos paper plant. This represents only a small increment of the total power required for manufacturing.

Non-Water Quality Environmental Impact--

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude. The costs of avoiding problems in these areas are not excessive.

Size and Age of Equipment and Facilities--

As noted in Section IV, the size range among asbestos paper manufacturing facilities is relatively narrow. Differences in size are insufficient to substantiate differences in control technology. This level of control technology is readily applicable to all facilities regardless of the age of the equipment or the structure.

Process Employed and Process Changes--

All facilities use similar manufacturing processes and produce similar waste water discharges. There is no evidence that operation of any process currently in use will substantially affect capabilities to implement this control technology. The implementation of this control technology does not require in-plant changes or modifications. Major developments in manufacturing processes in the future are not expected. This control technology can be applied so that upsets and other fluctuations in process operations can be accommodated without exceeding the effluent limitations.

Engineering Aspects of Application--

It is estimated that 70 percent of the asbestos paper manufacturing plants in the country use sedimentation facilities in addition to in-plant save-alls. Some of the treatment units will have to be upgraded in operation or capacity or both in order to achieve the effluent limitations recommended in this document. This level of control is judged to be adequate and is the average of the best in the industry. Only one plant is known to manufacture only asbestos paper and achieve a higher level of control.

Asbestos Millboard

No discharge of process waste waters has been achieved by two of the seven know millboard manufacturing facilities in the country. This level of control technology is judged to be applicable to all millboard plants that discharge to navigable waters.

Costs and Energy Requirements--

The investment costs of implementing this level of control technology are estimated to be $260,000 for all manufacturing facilities in this subcategory. The added annual costs are estimated to be $191,000. The additional energy requirements are estimated to be 37 kw (50 hp) or less for the typical plant. This represents only a small additional increment of the total power required for manufacturing.

Non-Water Quality Environmental Impact--

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude. The cost of avoiding problems in these areas is not excessive.

Size and Age of Equipment and Facilities--

As noted in Section IV, the size range among asbestos millboard manufacturing facilities is relatively narrow. Differences in size are insufficient to substantiate differences in control technology. This level of control technology is readily applicable to all facilities regardless of the age of the equipment or the structure.

Processes Employed and Process Changes--

All facilities use similar manufacturing processes and produce similar waste water discharges. There is no evidence that operation of any process currently in use will substantially affect capabilities to implement this control technology. The implementation of this control technology does not require in-plant changes or modifications. Major developments in manufacturing processes in the future are not expected. This control technology can be applied so that upsets and other fluctuations in process operations can be accommodated without exceeding the effluent limitations.

Engineering Aspects of Application--

As noted above, two of the seven millboard manufacturing facilities in the country achieve complete recirculation of all process waste waters. One plant uses a large lagoon, but the other uses only save-all units. This level of control technology is judged to be the average of the best and attainable by all plants in this product subcategory.

Asbestos Roofing

Sedimentation of process waste waters (contaminated cooling water) from the manufacture of asbestos roofing products is commonly practiced. Skimming and absorptive filtration is often included to remove oils and other organic materials to acceptable levels. This control technology is the least costly alternative known to be effective with these wastes.

Costs and Energy Requirements--

The total investment costs of implementing this control technology are estimated to be $120,000 for all manufacturing facilities in this product subcategory. The added annual costs are estimated to be $50,000. The additional energy requirements are estimated to be 11 kw (15 hp) or less for the typical plant. This power requirement represents only a small increment of the total plant's energy needs.

Non-Water Quality Environmental Impact--

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude. The costs of avoiding problems in these areas are not excessive.

Size and Age of Equipment and Facilities--

As noted in Section IV, the size range among asbestos roofing manufacturing facilities is relatively narrow. Differences in size are insufficient to substantiate differences in control technology. This level of control technology is readily applicable to all facilities regardless of the age of the equipment or the structure.

Processes Employed and Process Changes--

All facilities use similar manufacturing processes and produce similar waste water discharges. There is no evidence that operation of any process currently in use will substantially affect capabilities to implement this control technology. The implementation of this control technology does not require in-plant changes or modifications. Major developments in manufacturing processes in the future are not expected. This control technology can be applied so that upsets and other fluctuations in process operations can be accommodated without exceeding the effluent limitations.

Engineering Aspects of Application--

It is estimated that approximately 35 percent of the asbestos roofing manufacturing plants (saturation facilities) use this control technology or the equivalent. This is the highest level of control known to be used in treating waste waters in this product subcategory. This technology was judged to be the average of the best and to be an adequate level of control. This control technology is well understood and no unusual problems should arise in applying it at all facilities in this subcategory that discharge to navigable waters. Although the nature of the waste are known imprecisely, the technology should be generally effective in reducing the pollutant constituents to the levels recommended in the effluent limitations.

Asbestos Floor Tile

The relatively limited data available on waste waters from floor tile manufacturing indicate that most of the oxygen demand is caused by insoluble materials that are removable by sedimentation, aided perhaps by the use of coagulants. Within this industrial category, there is no generally recognized treatment technology that is normally applied. The plants that do treat their wastes provide some form of sedimentation, skimming, filtration, or chemical treatment or some combination of these operations. Since the characteristics of the raw waste waters is not well defined and may vary widely among plants, the effectiveness of a given treatment technology at a particular location cannot be predicted as accurately as is possible with many industrial wastes.

Costs and Energy Requirements--

The total investment costs of implementing this level of control technology are estimated to be $520,000 for all manufacturing facilities in this subcategory. The added annual costs are estimated to be $195,000. The additional energy required is estimated to be 15 kw (20 hp) or less for the typical plant. This represents only a small increment of the total power requirement of a plant.

Non-Water Quality Environmental Impact--

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude. The costs of avoiding problems in these areas are not excessive.

Size and Age of Equipment and Facilities--

As noted in Section IV, the size range among asbestos floor tile manufacturing facilities is relatively narrow. Differences in size are insufficient to substantiate differences in control technology. This level of control technology is readily applicable to all facilities regardless of the age of the equipment or the structure.

Processes Employed and Process Changes--

All facilities use similar manufactruring processes and produce similar waste water discharges. There is no evidence that operation of any process currently in use will substantially affect capabilities to implement this control technology. The implementation of this control technology does not require in-plant changes, or modifications. Major developments in manufacturing processes in the future are not expected. This control technology can be applied so that upsets and other fluctuations in process operations can be accommodated without exceeding the effluent limitations.

Engineering Aspects of Application--

It is estimated that about half of the asbestos floor tile plants do not discharge to public sewerage systems are currently using this level of control technology. From the limited data available, this was judged to be an adequate level of control. It was also judged to be the average of the best currently in use by this subcategory of the asbestos manufacturing industry.

SECTION X
EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations that must be achieved July 1, 1983, are to specify the degree of effluent reduction attainable through the application of the Best Available Technology Economically Achievable. This control technology is not based upon an average of the best performance within an industrial category, but is determined by identifying the very best control and treatment technology employed by a specific plant within the industrial category or subcategory, or where it is readily transferable from one industry process to another.

Consideration must also be given to:

a. The total cost of application of this control technology in relation to the effluent reduction benefits to be achieved from such application;

b. energy requirements;

c. non-water quality environmental impact;

d. the size and age of equipment and facilities involved;

e. the processes employed;

f. process changes;

g. the engineering aspects of the application of this control

The Best Available Technology Economically Achievable also considers the availability of in-process controls as well as control or additional end-of-pipe treatment techniques. This control technology is the highest degree that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including "no discharge" of pollutants.

Although economic factors are considered in this development, the cost for this level of control is intended to be the top-of-the line of current technology subject to limitations imposed by economic and engineering feasibility. However, this control technology may be characterized by some technical risk with respect to performance and with respect to certainty of costs. Therefore, this control technology may necessitate some industrially sponsored development work prior to its application.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Based upon the information contained in Section III through VIII of this document, a determination has been made that the degree of effluent reduction attainable through the application of the Best Available Technology Economically Achievable is no discharge of process waste waters to navigable waters.

IDENTIFICATION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

This control technology for all subcategories of the asbestos manufacturing industry is recycle and reuse of all process waters and all cooling water that contacts the product or otherwise is exposed to contamination by pollutant constituents.

To implement this control technology requires that the quantity of fresh water supplied to the plant for manufacturing purposes equals the quantity leaving the plant with the product or that lost through evaporation. A combination of in-plant control measures to conserve water usage and end-of-pipe treatment technology will be required at most plants to apply this control technology.

RATIONALE FOR THE SELECTION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Asbestos-Cement Pipe

No discharge of process waste waters represents the ultimate level of control technology. All alternative technologies whereby no discharge of pollutant constituents could be achieved would be much more costly to implement.

Costs and Energy Requirements--

The total investment costs of implementing this level of control technology are estimated to be $1,900,000 for all manufacturing facilities in this subcateogry, or $1,040,000 more than the Best Practicable Control Technology Currently Available. The annual costs are estimated to be approximately $760,000, an added increment of $290,000. The energy requirements are estimated to be 56 kw (75hp) or less for the typical plant. This represents only a small increment of the total power required for manufacturing.

Non-Water Quality Environmental Impact--

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude. The costs of avoiding problems in these areas are not excessive.

Size and Age of Equipment and Facilities--

As noted in Section IV, the size range among manufacturing facilities in this product subcategory is not large and this control technology is equally applicable to all plants, regardless of differences in size. The age of the equipment and facilities also does not play a role in the applicability of this level of control technology.

Processes Employed and Process Changes--

All facilities in this category use similar manufacturing processes. There is no evidence that the minor process variations that do exist will substantially affect the applicability of this control technology. Some degree of change of process operation will be involved in implementing this technology and in-plant control measures will be required at most facilities. Major new developments in manufacturing processes in the future are not expected. This control technology can be applied so that upsets and other changes in manufacturing operations that result in fluctuations in waste volumes or characteristics can be accomodated without exceeding the recommended effluent limitations.

Engineering Aspects of Applications--

The implementation of this control technology implies that the quantity of fresh water taken into the manufacturing process be balanced by that leaving with the product. The capacity of the in-plant and end-of-pipe sedimentation units (save-alls, clarifiers, etc.) must be adequate to accommodate all surges in flow or additional holding tank volume will be required. This presents no unusual engineering problems. Additional scale control measures may be required.

There are two asbestos-cement pipe manufacturing facilities that are know to recircualte treated process waste water through the production line. Neither of these accomplish total recycle in the strictest sense of the term, however. One is part of a multi-product plant where all waste waters are treated and recirculated without discharge of effluent. The other facility recirculates much, but not all, of the treated waste water. There is no plant making only pipe that accomplishes zero discharge. Some problems relating to product quality were noted in one experimental trial of total recycle at a pipe manufacturing facility, and there is some element of risk involved in establishing this level of control technology. Additional research on the part of the industry will be necessary to implement this technology.

Asbestos-Cement Sheet

No discharge of process waste waters represents the ultimate level of control technology. All alternative technologies whereby no discharge of pollutant constituents could be achieved would be much more costly to implement.

Costs and Energy Requirements--

The total investment costs of implementing this level of control technology are estimated to be $1,290,000 for all manufacturing facilities in this subcategory, or $650,000 more than the Best Practicable Control Technology Currently Achievable. The annual costs are estimated to be approximately $980,000, an added increment of $540,000. The energy requirements are estimated to be 37 kw (50 hp) or less for the typical plant. This represents only a small increment of the total power required for manufacturing.

Non-Water Quality Environmental Impact

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude. The costs of avoiding problems in these areas are not excessive.

Size and Age of Equipment and Facilities--

As noted in Section IV, the size range among manufacturing facilities in this product subcategory is not large and this control technology is equally applicable to all plants, regardless of differences in size. The age of the equipment and facilities also does not play a role in the applicability of this level of control technology.

Processes Employed and Process Changes--

All facilities in this subcategory use similar manufacturing processes. There is no evidence that the minor process variations that do exist will substantially affect the applicability of this control technology. Some degree of change of process operation will be involved in implementing this technology and in-plant control measures will be required at most facilities. Major new developments in manufacturing processes in the future are not expected. This control technology can be applied so that upsets and other changes in manufacturing operations that result in fluctuations in waste volumes or characteristics can be accommodated without exceeding the recommended effluent limitations.

Engineering Aspects of Application--

The implementation of this control technology implies that the quantity of fresh water taken into the manufacturing process be balanced by that leaving with the product. The capacity of the in-plant and end-of-pipe sedimentation units (save-alls, clarifiers, etc.) must be adequate to accomodate all surges in flow or additional holding tank volume will be required. This represents no unusual engineering problems. Additional scale control measures may be required.

In addition to a sheet facility at the multi-product plant mentioned in the previous discussion of asbestos-cement pipe, there is one known asbestos-cement sheet products plant that accomplishes zero discharge of process waste waters most of the time. There are occasional periods when treated effluent overflow to the municipal sewerage system. This plant manufactures only a few of the many sheet products on the market today using the wet mechanical process. To what extent complete recirculation can be accomplished by all sheet plants making other products and using other processes is not known. That one plant has almost achieved zero discharge of pollutant constituents serves as the basis for recommending this level of control technology for this product subcategory.

Asbestos Paper

No discharge of process waste waters represents the ultimate level of control technology. All alternative technologies whereby no discharge of pollutant constituents could be achieved would be much more costly to implement.

Costs and Energy Requirements--

The total investment costs of implementing this level of control technology are estimated to be $1,040,000 for all manufacturing facilities in these subcategories, or $570,000 more than the Best Practicable Control Technology Currently Achievable. The annual costs are estimated to be approximately $400,000, an added increment of $275,000. The energy requirements are estimated to be 75 kw (100 hp) or less for the typical plant. This represents only a small increment of the total power required for manufacturing.

Non-Water Quality Environmental Impact--

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude. The costs of avoiding problems in these areas are not excessive.

Size and Age of Equipment and Facilities--

As noted in Section IV, the size range among manufacturing facilities in these product subcategories is not large and this control technology is equally applicable to all plants, regardless of differences in size. The age of the equipment and facilities also does not play a role in the applicability of this level of control technology.

Processes Employed and Process Changes--

All facilities in these subcategories use similar manufacturing processes. There is no evidence that the minor process variations that do exist will substantially affect the applicability of this control technology. Some degree of change of process operation will be involved in implementing this technology and in-plant control measures will be required at most facilities. Major new developments in manufacturing processes in the future are not expected. This control technology can be applied so that upsets and other changes in manufacturing operations that result in fluctuations in waste volumes or characteristics can be accommodated without exceeding the recommended effluent limitations.

Engineering Aspects of Application--

The implementation of this control technology implies that the quantity of fresh water taken into the manufacturing process be balanced by that leaving with the products. The capacity of the in-plant and end-of-pipe sedimentation units (save-alls, clarifiers, etc.) must be adequate to accommodate all surges in flow or additional holding tank volume will be required. This presents no unusual engineering problems. Additional scale control measures may be required.

There are two known asbestos paper manufacturing facilities that essentially achieve zero discharge. One is part of the multi-product plant mentioned above and the other is a plant that makes only paper. The former plant has no discharge and the latter has no discharge under certain conditions. This plant is connected to a public sewer and relief is available when necessary. Both facilities use a starch binder. The second one also makes paper with an elastomeric binder. When making this kind of paper, treated waste water is discharged. Whether a plant using elastomeric binders can achieve complete recirculation of all waste water is unknown today. Research on the part of industry will be necessary to detemine this. That complete recycle of water has been demonstrated on a sustained basis in one major segment of the asbestos paper manufacturing industry serves as the basis for recommending this level of control technology.

Asbestos Millboard

The recommended technology is the same as that in Section IX of the Document for Best Practicable Control Technology Currently Available. The rationale for this recommendation is fully discussed there.

Asbestos Roofing

No discharge of process waste waters (contaminated cooling water) represents the ultimate level of control technology. This can be accomplished by treating and cooling the waste water and re-using it or by use of a totally non-contact cooling system with containment of all leaks. The feasibility and costs of the second alternative depend upon individual plant characteristics and cannot be estimated. The discussion below applies, therefore, to the first alternative.

Costs and Energy Requirements--

The total investment costs of implementing this level of control technology are estimated to be $310,000 for all manufacturing facilities in this subcategory, or $190,000 more than the Best Practicable Control Technology Currently Achievable. The annual costs are estimated to be approximately $37,000. This is less than for the best practicable technology due to savings in fresh water costs. The energy requirements are estimated to be 18 kw (25 hp) or less for the typical plant. This represents only a small increment of the total power required for manufacturing.

Non-Water Quality Environmental Impact--

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude. The costs of avoiding problems in these areas are not excessive.

Size and Age of Equipment and Facilities--

As noted in Section IV, the size range among manufacturing facilities in this product subcategory is not large and this control technology is equally applicable to all plants, regardless of differences in size. The age of the equipment and facilities also does not play a role in the applicability of this level of control technology.

Processes Employed and Process Changes-

All facilities in this subcategory use similar manufacturing processes. There is no evidence that the minor process variations that do exist will substantially affect the applicability of this control technology. Some degree of change of process operation will be involved and in-plant control measures will be required at most facilities. Major new developments in manufacturing processes in the future are not expected. This control technology can be applied so that upsets and other changes in manufacturing operations that result in fluctuation in waste volumes or characteristics can be accomodated without exceeding the recommended effluent limitations.

Engineering Aspects of Application--

There are no know asbestos roofing facilities (saturation plants) that reuse the contaminated contact cooling water after treatment. The full extents of the problems involved are not known, but technology is available from other industrial areas to accomplish this level of control. Some facilities do not use contact cooling systems. The feasibility of converting a contact cooling system into a non-contact system is also not known.

Asbestos Floor Tile

No discharge of process waste waters (contaminated cooling water) represents the ultimate level of control technology. This can be accomplished by treating and cooling the waste water and reusing it or by use of a total non-contact cooling system with containment of all leaks. The feasibility and costs of the second alternative depend upon individual plant characteristics and cannot be estimated. The discussion below applies, therefore, to the first alternative.

Costs and Energy Requirements--

The total investment costs of implementing this level of control technology are estimated to be $1,270,000 for all manufacturing facilities in this subcategory, or $750,000 more than the Best Practicable Control Technology Currently Achievable. The annual costs are estimated to be approximately $310,000, an added increment of $115,000. The energy requirements are estimated to be 26 kw (35 hp) or less for the typical plant. This represents only a small increment of the total power required for manufacturing.

Non-Water Quality Environmental Impact--

There is no evidence that application of this control technology will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude. The costs of avoiding problems in these areas are not excessive.

Size and Age of Equipment and Facilities--

As noted in Section IV, the size range among manufacturing facilities in this products subcategory is not large and this control technology is equally applicable to all plants, regardless of differences in size. The age of the equipment and facilities also does not play a role in the applicability of this level of control technology.

Processes Employed and Process Changes--

All facilities in this subcategory use similar manufacturing processes. There is no evidence that the minor process variations that do exist will substantially affect the applicability of this control technology. Some degree of change of process operation will be involved in implementing this technology and in-plant control measures will be required at most facilities. Major new developments in manufacturing processes in the futre are not expected. This control technology can be applied so that upsets and other changes in manufacturing operations that result in fluctuations in waste volumes or characteristics can be accomodated without exceeding the recommended effluent limitations.

Engineering Aspects of Application--

There are no known asbestos floor tile manufacturing facilities that reuse the contaminated contact cooling water after treatment. This process waste water contains a wide variety of materials and the precise treatment requirements are unknown. The quantity of contact cooling water varies among facilities and some reportedly do not use contact cooling. The feasibility of converting a contact cooling system into a non-contact system is undetermined.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

Defined standards of performance are to be achieved by new sources of waste waters. The term "new source" is defined to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance."

In defining performance standards for new sources, consideration must be given to:

a. Costs and energy requirements;

b. Non-water quality environmental impact;

c. Process changes including changes in raw material operating methods, and recovery of materials; and,

d. Engineering aspects of application

IDENTIFICATION OF NEW SOURCE PERFORMANCE STANDARDS

In the design and operation of new manufacturing facilitiees, in-plant controls, and end-of-pipe technology will be required to meet the recommended standards. In the summary below, Best Practicable Technology Currently Available is identified as the 1977 level and Best Available Technology Economically Achievable, as the 1983 level. The technologies are described in Section IX and X for each product subcategory.

Asbestos-cement pipe	1977
Asbestos cement sheet	1983
Asbestos paper (starch binder)	1983
Asbestos paper (elastomeric binder)	1977
Asbestos millboard	1977
Asbestos roofing	1983
Asbestos floor tile	1983

EFFLUENT REDUCTION ATTAINABLE THROUGH APPLICATION OF NEW SOURCE PERFORMANCE STANDARDS

Based on the information contained in Section III through VIII of this document, a determination has been made of the degree of effluent reduction attainable through application of the New Source Performance Standards. These are fully outlined in the appropriate parts of Section IX and X.

RATIONALE FOR THE SELECTION OF NEW SOURCE PERFORMANCE STANDARDS

Asbestos-Cement Pipe

The factors considered in selecting the standard for new asbestos-cement pipe manufacturing facilities are discussed below.

Costs and Energy Requirements--

The costs of incorporating the necessary in-plant control and end-of-pipe technologies into the design of a new facility should be less than those for adding them in an existing plant. The energy requirements should be the same or less.

Non-Water Quality Environmental Impact--

There is no evidence that application of this standard will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude.

Process Changes--

There are no changes in the basic manufacturing process available that would achieve greater effluent reductions than attainable through application of this standard. In-plant measures to conserve water and materials should be incorporated into new facilities. There are no significant benefits to be derived from the use of batch operations or by the use of other raw materials. There is currently a high degree of materials recovery from the waste streams in facilities in this subcategory. The final wastes have no known economic value and disposal on land by appropriate methods will be necessary.

Engineering Aspects of Application--

It has not yet been demonstrated that an asbestos-pipe manufacturing facility can accomplish complete recircualtion of waste waters, or zero discharge of pollutants. For this reason, the New Source Performance Standard is Best Practicable Control Technology Currently Available. As future developments dictate, this standard may be revised.

Asbestos-Cement Sheet

The factors considered in selecting the standard for new asbestos-cement sheet manufacturing facilities are discussed below.

Costs and Energy Requirements--

The costs of incorporating the necessary in-plant control and end-of-pipe technologies into the design of a new facility should be less than those for adding them in an existing plant. The energy requirements should be the same or less.

Non-Water Quality Environmental Impact--

There is no evidence that application of this standard will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude.

Process Changes--

There are no changes in the basic manufacturing process available that would achieve greater effluent reduction than attainable through application of this standards. In-plant measures to conserve water and materials should be incorporated into new facilities. There are no significant benefits to be derived from the use of batch operations or by the use of other raw materials. There is currently a high degree of materials recovery from the waste streams in facilities in this subcategory. The final wastes have nc known economic value and disposal on land by appropriate methods will be necessary.

Engineering Aspects of Application--

One facility manufacturing asbestos-cement sheet products essentially accomplishes zero discharge of pollutants. While this is judged to be insufficient demonstration that all existing sheet facilities can completely recycle all process waste waters today, it is believed that new facilities can be designed to achieve this level of control. Therefore, the New Source Performance Standard is Best Available Technology Economically Achievable.

Asbestos Paper (Starch and Elastomeric)

The factors considered in selecting the standards for new asbestos paper manufacturing facilities are discussed below.

Costs and Energy Requirements--

The costs of incorporating the necessary in-plant control measures and end-of-pipe technologies to the design of new facilities should be less than those for adding them in existing plants. The energy requirements should be the same or less.

Non-Water Quality Environmental Impact--

There is no evidence that application of these standards will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude.

Process Changes--

The different standards recommended for each of the asbestos paper subcategories is necessitated by differences in raw materials. When using elastomeric materials as binder, complete recycle of waste waters has not been demonstrated. There is no information available about possible changes in raw materials that would permit complete recycle in elastomeric binder systems.

There are no changes in the basic manufacturing process available that would achieve greater effluent reduction than attainable through application of these standards. In-plant measures to conserve water and materials should be incorporated into all new facilities. There are no significant benefits to be derived from the use of batch operations. There is currently a high degree of materials recovery from the waste streams in facilities in these subcategories.

Engineering Aspects of Application--

No discharge of pollutants has been demonstrated at at least one asbestos starch paper manufacturing facility. This serves as the basis for recommending that the New Source Performance Standard be Best Available Technology Economically Achievable for this subcategory. Complete recycle has not been demonstrated by a facility when making asbestos paper with an elastomeric binder. Therefore, the New Source Performance Standards for these facilities is Best Practicable Control Technology Currently Available.

Asbestos Millboard

The factors considered in selecting the standard for new asbestos millboard manufacturing facilities are discussed below.

Cost and Energy Requirements--

The costs of incorporating the necessary in-plant control and end-of-pipe technologies into the design of a new facility should be less than those for adding them in an existing plant. The energy requirements should be the same or less.

Non-Water Quality Environmental Impact--

There is no evidence that application of this standard will result in any unusual air pollution or solid waste disposal problems, either in kind or magnitude.

Process Changes--

There are no changes in the basic manufacturing process available that would achieve greater effluent reduction than attainable through application of this standard. In-plant measures to conserve water and materials should be incorporated into new facilities. There are no significant benefits to be derived from the use of batch operations or by the use of other raw materials. There is currently a high degree of materials recovery from the waste streams in facilities in this subcategory. The final wastes have no known economic value and disposal on land by appropriate methods will be necessary.

Engineering Aspects of Application--

Complete recycle of process waste waters has been demonstrated by facilites in the asbestos millboard category. Therefore, the New Source Performance Standard is Best Practicable Control Technology Currently Available, which is identical with Best Available Technology Economically Achievable.

Asbestos Roofing

The factors considered in selecting the standard for new asbestos roofing manufacturing facilities are discussed below.

Costs and Energy Requirements--

The costs of incorporating the necessary in-plant control and end-of-pipe technologies into the design of a new facility should be less than those for adding them in an existing plant. The energy requirements should be the same or less.

Non-Water Quality Environmental Impact--

There is no evidence that application of this standard will result in any unusual air pollution or solid waste disposal problems, either in kind or magitude.

Process Changes--

There is some limited information available that indicates that new asbestos roofing facilites could be designed to operate without contact cooling water systems. No major changes in the basic manufacturing process should be required to operate in this manner. There are no significant benefits to be derived from the use of batch manufacturing operations. Changes in raw materials might be beneficial if treatment and reuse of the contaminated cooling waters are determined to be the most feasible method of meeting this standard. There is no information, however, about raw materials that could be substituted. The materials in the waste stream are present in low levels and contaminated form. They have no significant economic value if recovered.

Engineering Aspects of Application--

Complete recycle of contaminated cooling water has not been demonstrated by facilites manufacturing asbestos roofing products. It is believed that through either the use of control technologies available in other industrial segments or by elimination of contact cooling water systems, this level of control can be achieved in new facilities. Therefore, the New Source Performance Standard is Best Available Technology Economically Achievable.

Asbestos Floor Tile

The factors considered in selecting the standard for new asbestos floor tile manufacturing facilities are discussed below.

Costs and Energy Requirements--

The costs of incorporating the necessary in-plant control and end-of-pipe technologies into the design of a new facility should be less than those for adding them in an existing plant. The energy requirements should be the same or less.

Non-Water Quality Environmental Impact--

There is no evidence that application of this standard will result in any unusual air pollution or solid waste disposal problems, either in kind or magitude.

Process Changes--

Several floor tile manufacturing facilities currently operate with non-contact cooling water systems entirely. It is believed that new facilities can incorporate such systems without significant changes in process being necessary. Even with non-contact cooling, in-plant control measures will be necessary to reduce leakage to an acceptable level. Dry cleaning methods should be used to reduce water usage.

Changes in raw materials would not affect any appreciable effluent reduction. Materials recovered from the waste stream have no known economic value.

Engineering Aspects of Application--

Complete recycle of contaminated cooling water has not been demonstrated by facilities manufacturing asbestos floor tile products. It is believed that through either the use of control technologies available in other industrial segments or by elimination of contact cooling water systems, this level of control can be achieved in new facilities. Therefore, the New Source Performance Standard is Best Available Technology Economically Achievable.

SECTION XII

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SECTION XIV

GLOSSARY

Beater

A wet mixer used to separate the fibers, mix the ingredients, and provide a homogeneous slurry.

Binder

A chemical substance mixed with asbestos and other ingredients to bond them together.

Blinding

The plugging by fibers and binder of the pores in carrier felts and holes in cylinder screens thereby reducing or preventing the flow of water through the felt or screen.

Calender

A machine designed to give paper a smooth surface by passing it between a series of pressure rollers.

Elastomeric Paper

Paper made with a synthetic or natural rubber binder.

6. Felt

An endless belt of heavy porous cloth.

Mottle

Solid color granulated tile chips that are made and fed into tile production lines to provide color and pattern.

Vacuum Box

A box with a long, narrow opening positioned just below or above the felt in a paper machine. The vacuum maintained in the box draws water out of the sheet of fiber through the felt and into the box.

Whipper

A rotating paddle designed to release fiber or other particulate matter from a paper, pipe, or millboard machine carrier felt by beating the felt as it moves through the machine.

TABLE 10
METRIC UNITS
CONVERSION TABLE

MULTIPLY (ENGLISH UNITS)		by	TO OBTAIN (METRIC UNITS)	
ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram-calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/ kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555 (°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	kilowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	ton	0.907	kkg	metric tons (1000 kilograms)
yard	yd	0.9144	m	meters

*Actual conversion, not a multiplier

*U.S. GOVERNMENT PRINTING OFFICE:1974 546-318/362 1-3